TRANSITIVITY AND THE REPRESENTATION OF STIMULUS RELATIONS BY YOUNG CHILDREN

by

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THESIS DECLARATION

The work reported in this thesis is my own, having been completed within the normal terms of reference of supervision (by Dr. B.O. McGonigle) in the Faculty of Social Sciences, Edinburgh University.

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ABSTRACT

The thesis describes experiments carried out with children and squirrel monkeys designed to challenge the claim by Bryant and Trabasso (1971) that children as young as four can make genuine transitive inferences. Bryant and Trabasso demonstrated their claim using a five-term modification of classical transitivity tasks (e.g. A >B; B >C; A?C). Several experimental variations of the design of their five-term problem are reported, involving verbal and non-verbal conditions. The results of these experiments show that the transitive choice profile which obtains under specifiable conditions of training and test is attributable to psychological mechanisms which do not necessarily implicate deductive operations.

Instead, the results are interpreted as support for James's (1891) distinction between "reasoning distinctively" and thought based on "associative sequence". Contrary to Bryant and Trabasso's claim, it is concluded that the solution of the five-term transitivity problem by young children is based on "empirical thinking" which in James's terms is "reproductive" rather than "productive".

CHAPTER ONE

When does the child reach the age of reason? At what stage in his development is he considered capable of logical thought? Tradition both ecclesiastical and civil would suggest that it is not until the age of seven and beyond that the child can be considered truly rational. This view has been confirmed in the laboratory by Piaget and his co-workers (1928, 1952, 1953, 1956 and 1964). Following the use of the "clinical method" where the child's errors on standard "intelligence" tests were followed up in an attempt to identify the causal factors at work in producing them (errors are assumed to be largely determined by the structure of "thought" and are not the random result of "ignorance" or "mistake"), Piaget concludes:

> "It is no exaggeration to say that there is no logical reasoning before the age of 7 - 8." (1928 p 234).
>
> "About the age of seven, a fundamental turning point is noted in the child's development. He becomes capable of a certain logic." (1974 p 20).

For Piaget, then, reasoning is a major feature of intellectual growth and its appearance at seven marks only the beginning of logical development but not its summit. At the first "logical" stage - the stage of Concrete Operations between seven and eleven years of age - the child's "logic" is very much tied to a given concrete situation. For example, a child at this stage is able to rearrange a random array of differently sized sticks into an ordered series. However, he seems to be unable to seriate information presented to him in more abstract and general terms, i.e. when the information is presented linguistically. It is only at around the age of eleven to twelve (the beginning of the Formal Operational stage) that a child is capable of reasoning, by co-ordinating propositional statements and thereby creating an ordered series. Perhaps Piaget's best known illustration of this is the test adapted from Burt (1919), in which a child is given the following information: "Edith is fairer than Suzanne; Edith is darker than Lili". He is then asked "Which is the darkest (fairest), Edith, Suzanne or Lili?". Children under twelve years of age do not solve this problem correctly and normally conclude that Suzanne is the fairest and Lili the darkest.

Piaget believes that such difficulties encountered by children originate in their lack of understanding of the "relativity of ideas" (1928, p 87). While relations may be easily perceived (1964, pp 5 and 10) they do not appear to have "psychological existence". That is, relations are not fully grasped as relations, and they do not carry for the child their logical implication, e.g. "Paul is my brother" does not imply "I am Paul's brother" (1928, p 87). More specifically, Piaget believes that relations are actually converted into judgments of membership. For example, he describes the child's response to the "Edith, Lili and Suzanne" problem in the following way:

> "Instead of tackling the matter by judgments of relation, i.e. by making use of such expressions as "Fairer than" etc., the child deals simply in judgments of membership, and tries to find out with regard to the three girls whether they are fair or dark (speaking absolutely). It is exactly as though he reasoned as follows: Edith is fairer than Suzanne, so they are both fair; Edith is darker than Lili, so they are both dark; therefore Lili is dark, Suzanne is fair and Edith is

between the two." (1928, p 87).

He concludes that judgments of relation are "substituted by judgments of membership".

The three-term series used by Piaget and Burt was later adapted by other investigators. Tests of transitive reasoning, as they are sometimes known, fall roughly into two categories.

a) The verbal versions similar to the 'Edith, Suzanne and Lili' problem. These are studied largely in connection with the development of formal operations and the processes of adult reasoning (Hunter, 1957; de Soto et al, 1965; Huttenlocher, 1968, a, b, c; Clark, 1969, a, b; Johnson-Laird, 1972; Trabasso et al, 1975, a, b, c).

b) Concrete versions of the problem using, e.g. visible size differences between sticks (Smedslund, 1963, 1965; Braine, 1964; Glick and Wapner, 1968; Youniss et al, 1968, 1970).

These studies have progressively unearthed more and more of the factors which are seen to play a role either in the achievement of a solution, or in the failure to solve the problem. For example, "judgment of membership" was included in only one of two sets of factors which were isolated by Hunter (1957)+ as likely to affect the strategy used in solving the three-term series. He studied the relative difficulty encountered by 64 eleven-year-olds and 32 sixteen-year-olds when presented with eight different problem "structures" and using three

+ The problem had been studied by this time in the context of four- and five-term series (Pinard, Barbeau, Laurendeau and Parant, 1954). Hunter considered the three-term version to make "for easier experimental investigation of at least some of those psychological processes which would seem to be fundamental to the solving of any type of series problem".

kinds of comparative terms, i.e. taller/shorter, warmer/colder, and happier/sadder. These are depicted below:

Problem Structure No.		Direction in which AC question is asked
I_1	$A > B : B > C$	$>$?
I_2	$A > B : B > C$	$<$?
II_1	$A > B : C < B$	$>$?
II_2	$A > B : C < B$	$<$?
III_1	$B < A : C < B$	$>$?
III_2	$B < A : C < B$	$<$?
IV_1	$B < A : B > C$	$>$?
IV_2	$B < A : B > C$	$<$?

Hunter believes that these structures are differentially susceptible to the following factors:

a) Atmosphere effects

An anecdotal example of an "atmosphere effect" (recorded prior to the decimalisation of the British monetary system) can be shown by the following "trick" played on a gullible bus passenger:

Conductor: "1/5d please"

Passenger gives him 2/-

Conductor: "Got a penny?"

Passenger gives him 1d

Conductor gives Passenger 6d change.

Atmosphere effects "predispose the thinker to accept that particular answer which 'looks right' although it may or may not be correct" (Hunter, 1957, p 289). One such effect is called by Hunter the effect of "direct statement", e.g. where the form of the question echoes the form of one of the premises and makes it more likely to determine the answer. On this basis, problem type II as illustrated above would be solved correctly, whilst problem type IV would be solved incorrectly. The other effect of atmosphere is Piaget's "judgment of membership", called by Hunter, "inclusiveness". This effect would also favour a correct answer on problem type II but an incorrect answer on problem type IV. Atmosphere effects occur, in short, when a subject is willing to solve the problem on the basis of a "global impression" or "feel".

b) Structural effects

These, by contrast, operate when the subject appears to make a "sequence of analytical judgments of relation and identity between successively encountered terms". The method of solution in this case involves constructing an isotropic series. An isotropic series is defined by Hunter as follows:

> "Two linked premises are <u>isotropic</u> when each contains the same unreversed relation and also when the common term is the referee of the first-encountered premise and the referent of the second premise, e.g. A > B : B > C and C < B : B < A. When the relation of one linked premise is the reverse of that contained in the other, then these premises are <u>heterotropic</u>, e.g. A > B : C < B."

Using James' "Axiom of Skipped Intermediaries" (1891) as collateral, Hunter assumes that the subject must derive an isotropic series before solving the problem, i.e. he must have some serial representation of the items described (relationally) in the linked premises. Thus, in the case of a heterotropic series, "the thinker must ...... make them isotropic by reorganising one or other of the premises" (Hunter, 1957).

Reorganising falls into two distinct categories: converting (required by structure II, i.e. A > B : C < B becomes A > B : B < C) and re-ordering (required by structure III, i.e. B < A : C < B becomes C < B : B < A). A third category includes two permutations of these first two. The first is converting-reordering (required by problem IV, i.e. B < A : B > C becomes C < B : B < A). The second (also required (as an alternative) by problem IV) is reversing-converting (i.e. back-tracking to the first premise and converting it: i.e. B < A : B > C becomes A > B : B > C).

In his study, Hunter looked at the relationship between the structural complexity of the task and its difficulty.+ Using solution time as a measure, he found that sixteen-year-olds were more sensitive to structural effects than eleven-year-olds; the younger subjects were more susceptible, however, to "atmosphere" effects. Of the difficulties experienced by younger children, some were identified as related to the structural characteristics of the problem but these were, in Hunter's terms, more "blurred". Younger children also experienced greater difficulty with the more "abstract" relations happier/sadder possibly because, as Trabasso, Riley and Wilson (1975) point out, they do not have "direct dimensional reference to physical objects". Overall, Hunter concluded that "increasing age brings increasing appreciation of the structural characteristics of series as such, together with an increasing skill in dealing with serial relations which are progress-ively more remote from the perceptual-motor level of behaviour" (p 286).

+ A similar attempt was made concerning grammatical and psychological complexity (Brown, 1973).

After Hunter, interest grew concerning the mechanisms of re-organising used by adults when attempting to solve the three-term series. Two major models of adult reasoning were put forward. One (de Soto, London and Handel, 1965, and Huttenlocher, 1968, a, b, c) developed the idea that the linear (isotropic) presentation was achieved by means of an imaginal spatial layout (either vertical or horizontal). These authors propose that the first premise is entered by "end-anchoring", i.e. the first term of the first premise is placed at the top (left)-most or bottom (right)-most position in the array (depending on the direction of the relation specified in that premise). The second premise is then entered (if necessary, after conversion) so that it continues in a direction consistent with the first premise. Thus, an isotropic series would be predicted as easier to construct if the first item of the first premise is also the first item of the series. If this is not the case, then a subject must proceed from the middle to the end of the series - a condition on which de Soto et al's subjects showed less than 50% correct performance. However, Huttenlocher (1968, a) has suggested that the most significant factor in "end-anchoring" (where different from the actual order of the premises) is the subject's perception of the "deep-structure" of the series, i.e. the subject/object relations within it. This conclusion is based on studies (1968, b, c) in which children, when asked to use real objects to "fit" the description, e.g. "the blue block is on top of the brown block", found the task easier if the object to be manipulated corresponded to the subject rather than the object of the sentence.

By contrast with the imagery models in which the answer may be "read off" from a spatial layout, Clark (1969 a, b) has put forward a "linguistic" model of reasoning in which the answer is thought to be achieved by operations performed on the words themselves. For example, to take the problem A > B : B > C : AC?, Clark presumes that the first premise, verbalised as "A is bigger than B", is converted into "A is more big and B is less big", and likewise with the second premise. The item stored twice, i.e. B, is then reclassified as "middle", "more" is reclassified as "most", and "less" as "least". The ultimate representation is thus: "A is most big, B is middle and C is least big". However, if the second premise were to be expressed as C < B or "C is smaller than B", then it would be stored as "C is more small and B is less small", and the final representation in this case would be: "A is most big, B is middle and C is most small". As Clark (1969 a, has suggested that the "marked" or negative pole of an antonymous pair requires more operations of definition than the unmarked or positive term, it can be seen that his model relates to difficulties subjects may have with the <u>linguistic</u> structure of the premises. As Johnson-Laird (1972) points out, "the representations involving ..... any marked item will be more complex than those involving ..... any unmarked item".

Thus it can be seen that, in general, models of adult and adolescent reasoning have been concerned with strategies of information reorganising used by subjects to achieve a logical solution. Investigations of child reasoning, on the other hand, have been aimed primarily at establishing the minimum age at which logical solutions can be said to occur at all. In this context several findings have been reported which appear to contradict Piaget's claim that the child is not in possession of logical operations before the age of seven. One such study was that carried out by Braine (1959). In Braine's study, children were trained to find candy under the longer of two sticks. They were then shown two imperceptibly different sticks, A and C, and shown in addition that a middle stick B was shorter than A and longer than C (when placed against them in turn). Braine found that 50% of children between the ages of 4.2 and 5.5 correctly concluded that the candy was under A. These results were interpreted by Braine as a demonstration of transitive reasoning. In making several criticisms of this experiment, Smedslund (1963, 1965) raised the possibility that seeing A as "longer" may lead straight away to the judgment that the candy was underneath it without taking B and C into account. Criticisms such as this one led to the adoption of a procedure which Youniss and Murray (1970) later described as the "conventional" one. The basic steps in this procedure are:

a) a child views/judges a stick A to be longer than stick B on trial 1;

b) he views stick B to be longer than stick C on trial 2; and

c) he is asked to judge stick A and C when presented some distance apart and differing indiscriminably in length. Subjects who judge, apparently without benefit of direct perceptual information, that A is longer than C are regarded as having demonstrated reasoning ability.

Even this procedure, however, was seen by Youniss and Murray to be susceptible to a criticism similar to the atmosphere effect in language problems - that Stick A is judged to be "longer" and may retain that label regardless of subsequent comparisons. Youniss and

Murray's own experiment (1970) controlled for this by apparently using a five-item series although they did not describe it as such. To remove the atmosphere or labelling effect they introduced terms X and Y to the (stick) series A B C. Three paradigms were used. In the first, X was shown to be bigger than A, Y to be smaller than C, A to be bigger than B and B to be bigger than C. In the second, X and A were equal and B and C were equal, and in the third Y and C were equal, and A and B were equal. In all three tests children were asked to judge (finally) A versus C. Essentially therefore these paradigms consisted of the presentation of a five-term heterotropic series, e.g. $A \geqslant B$: $E \leqslant D$: $B \geqslant C$: $C \geqslant D$. The criteria for success employed by Youniss and Murray were:

(i) Subjects were required to succeed on all three paradigms.

(ii) They were required to succeed on a test of seriation (considered by Piaget to be collateral to transitive reasoning).

Using these criteria, six-year-olds failed to behave "inferentially" and eight-year-olds performed only "with moderate success". Only 31% of the eight-year-olds succeeded on all three paradigms. Success on the seriation test was found to be predictive of better transitivity performance in the six-year-olds but could not be evaluated statistically for eight-year-olds as only three out of 32 failed on this test. An additional finding suggested that the order in which the information was presented could affect the response, i.e. AB, ED, BC, CD was more likely to produce a correct BD result than BC, CD, AB, ED. Youniss and Murray pointed out that "inferential judgments were still open to situational determinants" and concluded that eight years was a "'threshold' age level and not an age at which a transitive inference was a highly stable operation".

However, several investigators have suggested that a failure to produce a transitive response does not necessarily imply a lack of logical ability. In this vein, Bryant (1973b) has pointed out that no study carried out before 1971 took precautions that:

a) subjects could actually remember the premises at the time of test, and

b) results when "positive" were exempt from the "labelling" criticisms.

In order to incorporate these controls in a single experiment, Bryant and Trabasso (1971) devised a five-term version of the problem in which subjects were trained to remember four premises, $A > B$; $B > C$; $C > D$; $D > E$ of a five-term stick series $A > B > C > D > E$. They trained 60 subjects at three age levels - four, five and six years - and ensured that their retention of the training pairs was very good at the time of test. The terms in the series were denoted by the colour of the sticks, e.g. A - red, B - blue, C - yellow, D - green, E - black. The sticks were presented two at a time sunk into a wooden box so that equal portions of the sticks were visible. Subjects were asked "Which is taller?" or "Which is shorter?" and were given feedback. In Experiment 1, this was done by showing subjects the relative heights of sticks after every response and saying, e.g. "Yes, that's right, red is taller than blue". However, this was considered by the authors to be open to the criticism that subjects could remember the actual (absolute) sizes of the sticks, rather than the relational information they required for a transitive inference. In a second experiment reported in their paper, therefore, only the verbal feedback was given. The pairs were learned separately to a criterion of eight out of 10 correct on each pair, given in order from AB to DE (Phase I). They were then given "runs" of the four pairs, presented once each in random order, until they achieved a criterion of six out of six successive correct on each pair. Subjects were then given test pairs AC, AD, AE, BD, BE and CE along with the training pairs all presented in random order four times each and without feedback. All children showed significant transitive choice biases on BD. The probability of a transitive choice on BD in Experiment 2 was .82 for four-year-olds and .85 for five-year-olds. (No six-year-olds were run on this experiment.) The performance on BD was in fact lower than all the other test pairs. However, the retention performance on BC and CD was lower than on AB and DE and Bryant and Trabasso used this to argue that the lower performance on the crucial BD pairs is: "due to a failure of retention of the information contained in the initial comparisons". They demonstrated that the probability of a transitive bias on BD is fairly well predicted for their scores, by the joint probabilities of a correct response on BC and CD, i.e. $P_{BD} = P_{BC} \times P_{CD}$.

From results such as these, Bryant and Trabasso claim that "very young children are able to make transitive inferences extremely effectively. They can combine separate quantity judgments very well and they can do so at a far younger age than has generally been assumed." These investigators thus implicate only a single factor as crucial to the result. They suggest that in reasoning tasks, "an error might simply be due to a failure in memory and have nothing to do with inferential ability". Thus they claim "one must ensure that the child has retained the comparisons which he has to combine, if one is to infer whether or not he can make transitive inferences".

This claim provoked controversy (see Youniss and Furth, 1973) mainly over three points:

a) that they did not manipulate the memory variable;

b) that the children's solutions may have been "sub-logical"; and

c) that memory failure cannot be implicated as a factor in Piaget's (1960) demonstration of failure to reason transitively.+

Bryant (1973a) replied to this challenge by pointing out

a) that he had (subsequently) manipulated the memory variable and on a "trial by trial analysis of what the child remembered and of his ability to reach the correct inference" he apparently confirmed that there was a direct relation between the two (in Hinde and Hinde, 1973);

b) that Youniss and Furth had not themselves suggested a "sub-logical" explanation which would serve as an alternative to his own (Youniss and Furth, in fact, referred to Huttenlocher's spatial imagery model which Bryant described as perfectly compatible with a logical strategy); and

c) that Youniss and Furth had overlooked certain of Piaget's other non "spontaneous" experiments (1941, 1969a, 1969b, 1970) in which information subjects were required to combine was not apparently

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+ The studies they referred to were "measurement" tasks (Piaget, Inhelder and Szeminska, 1960) where subjects were considered to show transitive reasoning if they spontaneously used a middle term to judge the relative heights of two towers which were placed at different levels (and could not be judged directly). As this was an "active" task where the subject was not simply the recipient of certain information, Youniss and Furth argued that memory failure could hardly be a significant factor.

rehearsed nor were any steps taken to ensure that they could remember it.+

Thus, Bryant and Trabasso's experiment appears to be the first demonstration of transitive reasoning by young children in which precautions were taken to ensure that the child could remember the information given and that end-point labelling did not contribute - at least directly - to the crucial test results. If substantiated, their finding has major implications for developmental theories such as Piaget's, not the least of which would require a switch from the study of thinking to the study of memory per se as the significant developmental variable.

Convincing as Bryant and Trabasso's results are - at least at first blush - there remains a considerable burden of proof that the young child's choices in such tests are actually based on logical operations. Such operations, however, must be inferred from the choice data as, to quote Lutkus and Trabasso (1974) "They (Bryant and Trabasso) did not make use of the normal Piagetian criterion of verbal explanation to assert that a transitive inference had occurred. Rather they designed their experiment in such a way that success on the BD

+ On this last point neither set of investigators makes it clear, nor even seems to be aware, that Piaget (1928) has already taken pains to ensure that subjects could remember the information they were given:

> "Once the child has read the test often enough, once he has it sufficiently engraved upon his mind and difficulties of attention no longer exist, the logical difficulty still subsists of understanding how a little girl can be at the same time fairer than a second and darker than a third." (p 111).

pair, (the "symptom response") (to use Smedslund's term) could be explained in no other way than by a transitive inference." But is this the case? The work which is reported in this thesis represents a direct challenge to this position.

CHAPTER TWO

The hallmark of abstract, reflective thought is freedom from the spatio-temporal character of events as these are perceived and sensed directly. Cognitive "structure" is not, thus, a direct reflection of (any) order endemic to a well behaved environmental layout (Gibson, 1966) but is a construction of the organism's, permitting an internal representation of hypothetical as well as actual events and relationships. As Piaget (1971) puts it, "the whole of logic consists in establishing invariant schemata aimed at organizing into thought form the irreversible stream of external happenings" (p 151). Such freedom from stimulus control is gained, as Bruner (1966) puts it "..... through mediating processes ..... that transform the stimulus prior to response. ..... A theory of growth that does not attempt an account of these mediating processes and of the nature of the transformations they make possible is not very interesting psychology." (p 5). One such account of these processes has recently been provided by Trabasso (1975), based on information-processing theory approaches where the internal representation is

> "..... a symbolic entity containing elements that are related to one another in some defined way, which is constructed by the person in response to task demands and stored in memory for related purposes. This representation is constructed by processing stimuli and can be used to construct other representations, access descriptive information and retrieve properties of elements in response to inferential questions."
> (Trabasso, Riley and Wilson, 1975)

In common with logical (Hunter, 1957) and imagery (de Soto et al, 1965, and Huttenlocher, 1968) models, the representation achieved by the problem solver is seen to be of a linear order type, constructed as a result of the integration of relational information into an ordered set and subsequently allowing an internal "read off" of the relative position of the items thus stored. At the time of test, therefore, no co-ordination of the premises is required of the subject. The crucial integrative processes are considered to occur during the training phase of the problem. Evidence on the linear aspect of representation is considered by Trabasso to centre on two points:

a) A serial position effect is observed in the training data. This is regarded by Trabasso as "prima facie" evidence for an underlying linear order code.

b) During transitive tests the reaction times for non-adjacent items in the series are generally lower than the reaction times for adjacent items. This result is interpreted by Trabasso et al (1975) as indicating that "subjects did not engage in deductive reasoning at the time of test in order to make comparative length inferences". Instead the greater the psychological distance for the various items on a linear scale, the faster will be the choice time.

But what of the evidence that integration involving co-ordination of pairs occurs at all? Might the essentially serial nature of the training task leading to the learning of what is essentially an isotropic series not lead to some simple form of representation which permits at least one alternative strategy to co-ordination of premises <u>either</u> during training <u>or</u> at the time of test? The first experiment reported here is addressed to this question. The second experiment extends the enquiry along these lines through the provision of genuine heterotropic series requiring transformation by subjects if a correct solution is to be achieved.

EXPERIMENT 1

RATIONALE

The five term series as used by Bryant and Trabasso (1971) may be considered an example of a serial learning task. Certainly serial learning effects are apparent in their retention data. (Retention scores show a bow-shaped profile with the middle pairs emerging as the more difficult ones). In the initial training phase the pairs are trained in an order isomorphic with the (isotropic) form considered by many investigators as the psychologically necessary order which the subject must first achieve before any genuine (transitive) solution can be reached. The fact that a random phase follows on from this should not obscure the point that strong primacy over recency effects could well ensure a form of representation of the series by subjects, which requires no transformation of order whatsoever. In short, a much simpler strategy based on serial "mapping" may be made possible by Bryant and Trabasso's "serial" training phase. If this were the case, however, it might be expected that the random phase produces a decrement in training performance which would be reflected in the retention and "inference" test scores (assuming, for the time being, a direct relationship between retention and the test performance on non-adjacent pairs). Some evidence for this certainly exists in Bryant and Trabasso's data. Firstly they suggest that some special difficulty attaches to the random phase - particularly in the case of the youngest group:

> "All groups learned the initial (direct) comparisons rapidly. In the first phase of training there seemed to be no age differences in speed of learning. In the second phase, however, the four-year-old children made more errors

than the other two age groups who were not significantly different from each other."

Secondly, overall retention is well below 100% and thirdly, the BD scores are, as the authors, themselves, put it, "less than perfect".

However, a decrement produced by the random phase could be more directly tested by comparing a group of subjects trained exactly according to Bryant and Trabasso's procedure (i.e. with a separate pair, serial phase followed by a concurrent random phase) with another group for whom serial training is conserved throughout.

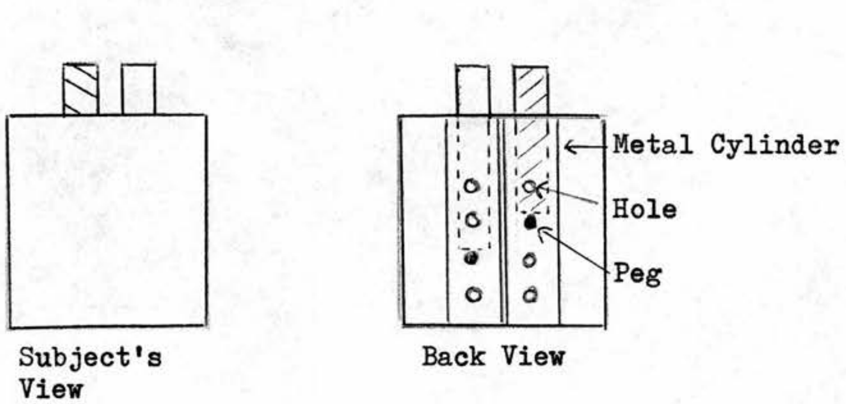
PILOT STUDY

Six "pilot" subjects were trained using a box which was designed as far as possible according to the description Bryant and Trabasso (1971) gave of their own apparatus:

> "The rods were presented in pairs throughout the experiment. The pairs were always presented in such a way that each rod protruded from the top of a container by one inch. The equal protrusion was achieved by sinking bores of different lengths in the container box."

The box used in this study is depicted below.

FIGURE 1.



The behaviour and comments of these subjects, however, suggested that, despite repeated explanations about the way in which the stimuli were contained in the box, they could only solve the questions by seeking minute (and possibly imagined) variation in the portions of the sticks actually presented. Several children would bend down and peer closely at the sticks, saying, for example, "I wanted to take a good look at them first and not make a mistake", "it's a wee bit of a different size", or "it looks longer". The presentation was therefore changed to the one described below as it was thought that the difficulty may have been related to the fact that the sticks may have appeared to have been somehow "suspended" in an unlikely manner.

EXPERIMENT 1

SUBJECTS

Subjects for this and all the other experiments reported in these chapters were drawn from a set of corporation primary and nursery schools in the centre of Edinburgh. In all schools, the subjects were from very mixed socio-economic backgrounds, ranging from "professional" to "working-class" homes. Several children belonged to one-parent families. The subjects included one West Indian girl, one Indian girl and one Icelandic girl. The rest were British.

Subjects for Experiment 1 were six pre-school and six school-children with a mean age of 4 years 11 months and a range of 4.10 to 5.2. There were six boys and six girls.

STIMULI

The stimuli were wooden cylindrical sticks of diameter $\frac{1}{2}$". The set of sticks used and the subsets in which they were presented to the subject are shown in Table 1. (over).

TABLE 1. Stimulus Set

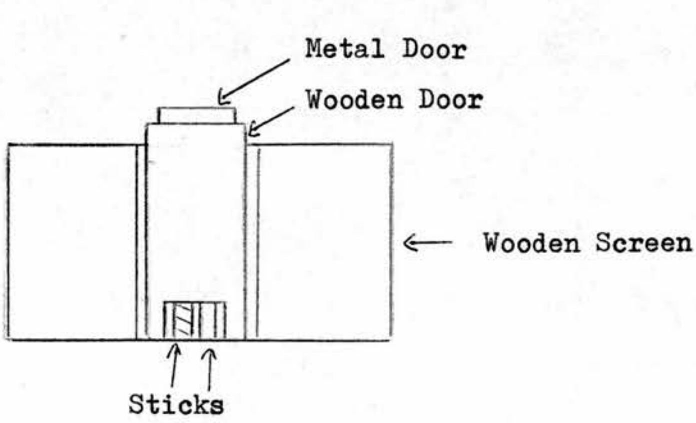
Subsets:		Pair 1		Pair 2		Pair 3		Pair 4	
Stick:		A	B	B	C	C	D	D	E
*Colour:	eg	Red	Yellow	Yellow	Blue	Blue	White	White	Green
Length:	(a)	$2\frac{1}{2}$"	$3\frac{1}{4}$"	$3\frac{1}{4}$"	4"	4"	$4\frac{3}{4}$"	$4\frac{3}{4}$"	$5\frac{1}{2}$"
	(b)	$5\frac{1}{2}$"	$4\frac{3}{4}$"	$4\frac{3}{4}$"	4"	4"	$3\frac{1}{4}$"	$3\frac{1}{4}$"	$2\frac{1}{2}$"

* Colour was counterbalanced according to a Latin Square Design

APPARATUS

The sticks could be placed, two at a time, half an inch apart in a wooden base which supported them in an upright position behind a wooden screen to which the base was affixed. The screen was 12" by 7" and was painted dark red. A white-painted, vertically-sliding door with a cut-out aperture (3" wide) could be moved up and down in front of the sticks, so that when completely lowered it revealed an equal (2") portion of the bases of the stimuli but obscured their actual extents. A second sliding door made of sheet metal moved up and down behind the wooden door such that when completely lowered it totally obscured the stimuli. A diagram (not drawn to scale) of the apparatus is shown in Figure 2.

FIGURE 2



DESIGN

Subjects were randomly assigned to one set of five sticks and randomly assigned to one of two groups: Replication (six subjects) and Serial (six subjects). Half the subjects in each group were given length series (a), while half were given length series (b) (see Table 1.). (It should be noted that as subjects did not actually see the relative lengths of the sticks; the provision of a physical series was for the experimenter's benefit during training)

PROCEDURE

Pre-training

The subject was familiarized with the apparatus by presenting him with a pair of unpainted sticks which corresponded in length to a randomly selected stimulus pair. The unpainted sticks were placed in the apparatus with both doors raised so that the subject could see their respective lengths. He was asked "Which is the longer one?" or "Which is the shorter one?" and, after he had responded by pointing, both doors were lowered. A strip of paper was slipped over the doors and the subject was asked to indicate with a pencil where each stick "came up to behind the doors". This was repeated five times. The left-right positions of the sticks were randomly varied. Three "shorter" and three "longer" questions were randomly interspersed. If a subject responded correctly to 6/6 questions and was prepared to represent on the paper the unseen length differences, then he was started on the training phases.

Training

Subjects viewed equal portions of the stimulus pairs and were trained to label each stick correctly as longer or shorter than the other stick with which it was paired. A trial commenced when a pair of sticks was placed in the apparatus with both doors lowered and facing the subject. The metal door was raised revealing an equal portion of the sticks and the subject was asked "Which is longer?" or "Which is shorter?". After responding subjects were given verbal corrective feedback, e.g. "no, that's wrong, blue is shorter" or "yes, that's right, red is longer" and the metal door was lowered. Training was conducted in two phases. In Phase I each pair was learned separately and in order from 1 to 4. Subjects were required to reach a criterion of 8/10 correct before proceeding to the next pair. In Phase II stimuli were presented in runs of four single presentations of each pair. For subjects in the Serial group, the pairs in every run were presented in order from 1 to 4. For subjects in the Replication group the pairs were presented in random order which was varied across runs. Both groups were required to reach a criterion of 6 out of 6 successive correct on each pair. "Longer" and "shorter" questions were counterbalanced across trials within every pair. The left-right positions of the sticks varied randomly across trials. Subjects were rejected[+] from the experiment if they required more than 30 trials on any pair in Phase I or more than 200 trials altogether in Phase II.

\+ Bryant and Trabasso did not report the rejection of subjects, the use of a rejection criterion, nor the acquisition performances. With no guidelines to follow, subjects trained at the outset of the above experiment were, in fact, rejected only after (in several cases) over a thousand trials on the random phase. The rejection criterion was introduced only after about two months of slow progress had been made with the experiment.

Testing

After successful completion of Phase II of Training, subjects were tested on all binary permutations of the stimulus set: their original training pairs, AB, BC, CD, DE, and the novel combinations AC, AD, AE, BD, BE and CE. These pairs were randomly ordered in blocks of 13 - where the "crucial" pairs BC, CD and BD were presented twice each and the others were presented once. Four blocks were given altogether to each subject. No corrective feedback was given. The left-right positions of the sticks was counterbalanced across the trials for a given pair. "Longer" and "shorter" questions varied randomly with the constraint that each pair was associated equally often with each type of question.

RESULTS+

Table 2 shows the numbers of subjects who were rejected at different points throughout the experiment.

TABLE 2. A. Number of Subjects Tested and Rejected

	No. of Subjects	Mean Age
Total started	33	4.10
Tested	12	4.11
Rejected	21	4.9

B. Experimental Phase during which Subjects were Rejected

	No. of Subjects
Pre-Training	5
Phase I	5
Phase II	10
Others	1

+ Bryant and Trabasso do not report the more detailed aspects of their data such as acquisition scores, etc. Riley and Trabasso, however, repeated Bryant and Trabasso's second experiment (1971, Experiment 2) with subjects of median age 4.8 and report the results in some detail (Riley and Trabasso, 1974, Experiment I). Where appropriate therefore, these results are included in the next section.

Table 3 shows the acquisition performance with data from Riley and Trabasso (1974) Experiment I in parenthesis.

TABLE 3. Mean Number of Trials to Criterion with Trial of Last Error (in brackets)

A. Separate Pair Training (Phase I)

Pair	AB	BC	CD	DE	Mean
Replication Group (N=6)	1.5 (1.7)	1.0 (1.0)	1.2 (1.3)	0.0 (0.0)	0.9 (1.0)
Serial Group (N=6)	1.0 (1.2)	1.8 (2.7)	1.0 (1.0)	0.5 (0.5)	1.0 (1.7)
[Riley and Trabasso's Group (N=20)	1.4 (3.1)	1.1 (2.2)	1.2 (2.2)	1.1 (2.1)	1.2 (2.4)]

B. Concurrent Pair Training (Phase II)

Pair	AB	BC	CD	DE	Mean
Replication Group (N=6)	4.0 (16.6)	4.5 (21.0)	7.5 (14.5)	3.8 (16.3)	4.9 (17.0)
Serial Group (N=6)	6.8 (13.8)	6.0 (22.5)	5.8 (16.2)	5.8 (15.2)	6.1 (16.9)
[Riley and Trabasso's Group (N=20)	2.6 (6.9)	5.4 (10.9)	4.1 (9.4)	3.1 (7.3)	3.8 (8.6)]

The Replication group and Riley and Trabasso's group show serial position effects with the middle pairs taking longer to learn than the end pairs.

Table 4 (over) shows the test performance of both groups combined.

TABLE 4. Probabilities of Correct Choices in Testing

	B	C	D	E
A	.83*	.69*	.75*	.71*
B		.71*	.58	.65
C			.67*	.77*
D				.83*

* Significantly above chance on a Binomial test. ($p < 0.01$.)

Table 5 (over) shows the test performance of the two groups. The Replication group is compared with Bryant and Trabasso's data (Experiment 2). Data from Riley and Trabasso are shown in parenthesis.

The test performances of the Replication and Serial groups were compared. The only significant difference between individual pairs across the two groups was on DE, where the Serial group were lower than the Replication group (x^2 sig. at $p < 0.01$). The Serial group performed better on all the test pairs when they were considered collectively (the "test" pairs refers here to pairs AC, AD, AE, BD, BE and CE) than did the Replication group (x^2 sig. at $p < 0.01$) while the training pairs (AB, BC, CD and DE) were not different when considered collectively.

Table 6 (p 30) compares the obtained BD scores reported above with the predictions made by Bryant and Trabasso's "memory hypothesis"; i.e. the Cartesian product of BC and CD.

TABLE 5. Probabilities of Correct Choices in Testing

Replication Group (N=6)

	B	C	D	E
A	.83*	.67	.62	.58
B		.72*	.53	.58
C			.72*	.79*
D				1.00*

Serial Group (N=6)

	B	C	D	E
A	.83*	.62	.88*	.83*
B		.70*	.64	.79*
C			.61	.75*
D				.67

Bryant and Trabasso
Expt. II (4 yr. olds) (N=20)

	B	C	D	E
A	.98*	.98*	.93*	.97*
B		.89*	.82*	.90*
C			.87*	.88*
D				.94*

Riley and Trabasso (N=20)

	B	C	D	E
A	.96*	.81*	.75*	.86*
B		.66*	.68*	.80*
C			.79*	.76*
D				.85*

* Significantly above chance on a Binomial Test ($p < 0.01$)

TABLE 6. Comparison of Obtained BD scores with Predictions made from the "memory hypothesis"

	Obtained Choice Bias on BD	Predicted Choice Bias on BD	Deviation
Replication and Serial Groups Combined (N=12)	.58	.48	-.10
Replication Group (N=6)	.53	.52	-.01
Serial Group (N=6)	.64	.43	-.21
Bryant and Trabasso (N=20)	.82	.77	-.05
Riley and Trabasso (N=20)	.68	.52	-.16
		Mean	-.16

DISCUSSION

The most striking findings from the first experiment are:-

a) the apparent inability of many subjects to learn the task at all, and

b) the poor test performances of both groups as compared with both Bryant and Trabasso's subjects and (to a lesser extent) those of Riley and Trabasso.

One plausible reason for this is suggested by Riley and Trabasso (1974) where they report that the original training box used by Bryant and Trabasso was a five-holed box in which the sticks were given fixed positions isomorphic with the series itself, i.e. A B C D E. The extent to which this provided a strong spatial cue in training is unclear. Bryant and Trabasso report taking measures to randomise the left-right positions within each pair: "the positions of the rods (left and right) were varied in an irregular order from trial to trial", and yet the manner in which this was achieved was not stated. At the very least, this would seem to involve a very clumsy procedure requiring either two boxes with direction opposed or a rotation of the apparatus to ensure symmetry. It is possible that two independent isotropic series were thus constructed, each with a visual analogue in real space. Bryant and Trabasso do not state whether the training box was used in testing or whether, at this point, recourse was made to a two-holed box.

As this was considered to be such an important aspect of the failure to replicate, a letter was sent to Dr. Bryant in June 1974, in which, amongst other things, he was asked for clarification on the above points. This letter is reproduced in the Appendix. No reply was ever received. To some extent the matter has now been clarified by Riley and Trabasso (1974) who acknowledge the strong possibility of artefact in the original experiment and who, themselves, took steps to eliminate it from their own study already cited in the results section. However, they did not use a two-holed box in training as an alternative. Rather, they screened off the irrelevant portion of a five-holed box when any two sticks were being viewed. Again it is unclear as to how counterbalancing or randomising of left/right positions was achieved, and (as either the box or the screen must be moved to reveal the "next" pair of stimuli) it still leaves open the possibility that strong spatial/directional cues may have operated.

Despite the poor performances of both groups, a distinct advantage appears to have operated for the Serial group. Not only was the BD bias higher for this group (and may well have reached significance had a larger "N" been used), but all the test pairs were better when considered collectively. However, the training pairs did not show an overall superiority (nor did any single training pair). Thus, the relationship between training and test performance does not appear to be a direct function of retention. This is confirmed by Table 6 which shows the failure of Bryant and Trabasso's "memory hypothesis" to account for the "less than perfect" BD scores, by the argument that these are a joint function of retention on BC and CD, i.e. $P_{BC} \times P_{CD} = P_{BD}$.

EXPERIMENT 2

RATIONALE

The only criterion for a "genuine transitive inference" in Bryant and Trabasso's experiment is the achievement of a correct answer to the BD question. The operations of transformation, inference or co-ordination must be inferred from the profile of correct choices. However, this inference has strong justification if the "correct" response is in fact a novel one, e.g. $B < A : B > C \therefore A > C$. The main problem with Bryant and Trabasso's "correct" response, e.g. $B > D$, is that the actual response, or relational term, is already part of the response set produced by training. It is, however, possible to devise versions of the paradigm (which also eschew difficulties with end-point labelling) which help to make explicit whether or not acts of transformation are normal in the context of such tests given to young children. Thus it was decided to compare a group of children for whom a transitive response was made likely by the training response set with a second group for whom it was not made likely unless these subjects could recover and exploit information not actually given. This was done by emphasising, for the first group, only those items congruent with the transitive direction of choice for BD, i.e. A B B C C D D E, and conversely for the other group, i.e. A B B C C D D E (the circled items are those emphasised in training).

EXPERIMENT 2

SUBJECTS

The subjects were six preschool and six schoolchildren with a mean age of 5.1 and a range of 4.9 to 5.3. There were six boys and six girls.

STIMULI

The stimuli and apparatus were identical to those used in Experiment 1.

DESIGN

The subjects were randomly assigned to one of two groups, A (six subjects) and B (six subjects). The training schemas for these groups are shown in Table 7 (over).

PROCEDURE

Training

Subjects were trained as in Experiment 1 but only one question type was used for a given pair (see Table 7.). The same rejection criterion was used as in Experiment 1.

Testing

THE PAIRS AB, BC, CD, DE + BD were presented in four blocks of single, randomly ordered presentations per pair. Both question types were asked within every pair. Question type varied randomly across trials with the constraint that each pair was associated with two "longer" and two "shorter" questions.

TABLE 7.

GROUP A (N=6)					GROUP B (N=6)				
Series Identification:	A B	B C	C D	D E	Series Identification:	A B	B C	C D	D E
Relative Size (Ss. 1-3):	S L	S L	S L	S L	Relative Size (Ss. 1-3):	S L	S L	S L	S L
(Ss. 4-6):	L S	L S	L S	L S	(Ss. 4-6):	L S	L S	L S	L S
Item Emphasised:	$\underline{A}$ B	$\underline{B}$ C	C $\underline{D}$	D $\underline{E}$	Item Emphasised:	A $\underline{B}$	B $\underline{C}$	$\underline{C}$ D	$\underline{D}$ E
Relation Trained (Ss. 1-3);	S	S	L	L	Relation Trained (Ss. 1-3):	L	L	S	S
(Ss. 4-6):	L	L	S	S	(Ss. 4-6):	S	S	L	L

RESULTS[+]

Table 8. shows the numbers of subjects who were rejected from the experiment (all of these subjects were rejected during Phase II of training).

TABLE 8. Number of Subjects Tested and Rejected

	No. of Subjects	Mean Age
Total Started	24	5.1
Tested	12	5.1
Rejected	12	5.1

Table 9 shows the acquisition performance with data from Riley and Trabasso (1974) Experiment II in parenthesis. (see over)

Table 10 (p 38) shows the test profile in terms of the responses to the original training question (O.R.) and in terms of the responses to the "reciprocal" relation (R.R.).

[+] As with Experiment 1, the results are compared where possible with data from Riley and Trabasso (1974). This data was obtained in an experiment (Experiment III) similar to Experiment 2, here. Riley and Trabasso only used one comparative term per pair, but used both comparatives across pairs, thus producing a heterotropic series. The structure of this series, however, did not correspond with either presented here as the comparative terms were alternated across pairs. Secondly, Riley and Trabasso do not report the retrieval of the reciprocal information separately in the test scores. For this reason, therefore, only the acquisition scores are directly compared in the following section.

TABLE 9. Mean Number of Trials to Criterion with Trials of Last Error (in brackets)

A. Separate Pair Training (Phase I)

Pair	AB	BC	CD	DE	Mean
Group A (N=6)	1.2 (2.2)	1.0 (1.2)	0.8 (1.5)	1.0 (1.8)	1.0 (1.7)
Group B (N=6)	1.3 (2.0)	0.5 (0.7)	0.8 (2.5)	0.3 (1.0)	0.8 (1.5)
[Riley and Trabasso's Group (N=7)	1.2 (2.7)	1.0 (2.0)	0.6 (0.8)	0.6 (1.4)	0.9 (1.7)]

B. Concurrent Pair Training (Phase II)

Pair	AB	BC	CD	DE	Mean
Group A (N=6)	6 (17.7)	4 (15.2)	5.5 (14)	5 (11.3)	5.1 (14.5)
Group B (N=6)	5.5 (22.5)	11.3 (29.7)	8.5 (33.2)	4.3 (18.3)	7.4 (25.9)
[Riley and Trabasso's Group (N=7)	7.3 (16.1)	12.3 (24.4)	8.6 (18.9)	3.4 (9.6)	7.9 (17.2)]

TABLE 10. Percentage of Correct Responses

	GROUP A				Transitive Choice Proportion on BD		GROUP B				Transitive Choice Proportion on BD
Series Id.	A B	B C	C D	D E		Series Id.	A B	B C	C D	D E	
O.R.	.92*	.75	1.00*	.75	.71	O.R.	.92*	.83*	.75	.92*	.58
R.R.	.50	.25	.50	.58		R.R.	.42	.67	.25	.75	

* Significantly above chance on a Binomial Test ($p < 0.05$)

Table 11 shows the overall performance to "original relation" questions in testing and "reciprocal relation" questions, for both groups combined.

TABLE 11. Percentage of Correct Responses

Pair	A B	B C	C D	D E	Mean
O.R.	.92*	.79*	.88*	.84*	.85*
R.R.	.46	.46	.38	.66	.49

* Significantly above chance on a Binomial Test ($p < 0.01$)

DISCUSSION

The above experiments were designed as a first exploratory investigation of Bryant and Trabasso's paradigm and of the possibility that the representational form of the task is not an achievement of the subject's own "operations" as a co-ordination or integration model would demand, but a reflection of the "structure" of the task.

Despite the tentative nature of these experiments and the initial (and rather surprising) inability to replicate Bryant and Trabasso's original results, the results from Experiment 2 suggest two fairly clear findings:

a) that subjects are unable to retrieve "reciprocal" information,

b) "transitive" responses can only be produced when the emphasis given to certain terms in training is congruent with the transitive direction of choice.

The transitive response on BD produced by group A is consistent with a "labelling" effect or effect of "direct statement" (Hunter, 1957). The chance performance produced by group B, however, suggests that "labelling" is not entirely straightforward, as a simple "echo" (Hunter, 1957) of B and/or D's label would predict a significant intransitive response. It seems, therefore, that "labelling", if it occurs, interacts with the overall directional structure of the series.

Overall, it can be seen that these subjects appear to be incapable of performing the operations of "conversion" implied by a co-ordination or integration model of transitive reasoning. The asymmetry between the groups shows furthermore the apparent lack of an "invariant" underlying strategy. It is therefore a significant finding in the context of models of constructive thinking for, as Glick and Wapner (1968) point out, "one can attribute an ability to a subject only if it can be shown that he performs in a relatively uniform manner across a variety of tasks calling that ability into play". It is a particularly significant finding in the context of Bryant's own suggestion (1977) that evidence against their position would have to show a variation in response profile despite identical training criteria:

> "Since we pointed out in 1971 that it was essential to check for memory in these experiments, no one has been able to produce one single instance of a child who can remember the information essential for an inference, but cannot combine it inferentially." (p 62)

If subjects can be regarded as deficient in the constructive abilities necessary to the performance of these tasks in a "logical" manner, can their (apparent) limitations be more specifically located? The results from the above experiment strongly suggest that the children's major difficulty is with the relational terms themselves. No such suggestion is made by Bryant and Trabasso who, in fact, conclude that an entirely linguistic form of the task (1971, Experiment 2) is no more difficult than one in which there is a concrete reference provided in the visual field. Bryant (1973b), furthermore, seems to imply that such linguistic solutions are based on a fundamental ability to perceive and understand relationships per se. When discussing children as young as four years of age, he says: "One certainty is that they are able to recognise broad relationships such as "larger" and "smaller" " (p 35). Nevertheless, the question of the child's competence in this sphere remains - for his understanding of relational terms is not well documented (see Nelson, 1976), and as Wales and

Campbell point out, it cannot be assumed that "this linguistic ability is available" [to the child] "simply because he uses these expressions in certain spontaneous situations". (Wales and Campbell, 1970)

In the absence of any direct evidence, therefore, Bryant's basis for belief that young children can both understand and co-ordinate relational terms at the logico/linguistic level is, at best, inferred from:

a) evidence from perceptual coding mechanisms which suggests that these are primarily relational. Using this evidence and ignoring the views of many investigators, e.g. Piaget (1964), Köhler (1930) and Werner (1948), that relational perception does not necessarily imply a perception of relations per se, Bryant fails to consider the distinction between perceptual and cognitive/linguistic levels of operation. He thus implies that linguistic codes are a direct reflection of perceptual ones.

b) the transitivity results of four year olds in the course of tests where "no visual feedback" has been given. The inference here is that such results could not have been achieved had the four-year-old been unable to comprehend the relational terms used. However, no direct evidence on relational term comprehension is provided.

The results of Experiments 1 and 2 reported here suggest strongly, however, that even in the so-called "no visual feedback" condition, a strong visuo-spatial cue was available to subjects and, furthermore, that the assumption that transitivity inevitably implies full relational comprehension and co-ordination is unwarranted.

This is not to say that the child of four has no comprehension whatsoever of such terms. The key issue is whether such a child understands the implications of relational terms delivered in a purely linguistic form so as to enable him both to seriate and reason deductively; or whether he has a much more rudimentary ability and requires, at this stage, direct perceptual provocation before he can use relational terms appropriately and thus effectively. As James (1891) points out

> "Relation is a very slippery word. It has so many different concrete meanings that the use of it as an abstract universal may easily introduce bewilderment into our thought. We must therefore be careful to avoid ambiguity by making sure, whenever we have to employ it, what its precise meaning is in that particular sphere of application." (p 149)

The experiments outlined in the next chapter report an attempt to discover what "concrete meanings", if any, relational terms may have for the young child.

CHAPTER THREE

As Wittengenstein (see Kenny, 1973) points out, relational terms do not "denote", i.e. stand in place of, or signify any material property of the world of a perceiver. As put, the genesis of relational terms would appear to be linguistic. This, certainly, is the view of the Behaviourist, Spence (1937a) who suggests that language transcends fundamental perceptual operations (which Spence believes to be based on the coding of "absolute" stimulus values).

Evidence for this view has been sought by followers of Spence (Kuenne, 1946; Alberts and Ehrenfreund, 1951) who believe that the "higher"-level relational mode of responding, if "mediated" by language, ought to be well-correlated with the ability to verbalise relational terms. This hypothesis was evaluated in the light of evidence obtained from transposition experiments where, conventionally, subjects are presented with two stimuli differing along a single dimension of change such as size, pitch or brightness and are then trained to choose, e.g. the bigger of the two. In a second, transfer, phase subjects are given a different pair of stimuli but differing along the same dimension as the original pair. "Relational" responding is presumed to be demonstrated by the transfer of response to the bigger, brighter, etc. of the two "novel" stimuli. In order to establish the degree of correlation between relational responding and "mediating" ability, it is necessary to couple transposition tasks with independent tests of verbal ability. Several techniques are used to do this. A pre-test may be given (Reese, 1961; Spiker, Gerjuoy and Shepard, 1956) in which subjects are asked verbally to point to e.g. the "larger" or "smaller" of two stimuli. Subjects are then categorised on the basis of their performance into a "premediating" or a "mediating" group. They may, on the other hand, be categorised post-experimentally (Stevenson and Bitterman, 1955). Occasionally, a "mediational" stimulus (such as, for example, a nonsense word) is actually trained in the context of the experiment itself and subjects thus trained are compared with a control group who were given no "mediational" stimulus. Overall, the results of these kinds of experiment suggest a relationship between mediation ability and the lack of the "Distance Effect" (a restriction of the range of values across which a subject will "transpose"; Ehrenfreund, 1952; Honig, 1962; Kuenne, 1946; Spence, 1937b),but the conclusion that this is a direct result of an increased ability to respond relationally is far from clear (see Reese, 1968). Many negative results and confounding factors (not the least of which is the increase in the chronological age of the subject (Reese, 1962) make the overall results from Mediation experiments far from conclusive. Even where verbal instructions have been found to affect the kind of response given in transposition tests, i.e. "relative" or "absolute", (Zeiler and Salten, 1967; Riley et al, 1966), it is doubtful that such consequences of instruction are the result of language per se. McGonigle and Jones (1977b) have found similar effects using non-human subjects when the "judgmental criteria" manipulated are purely perceptual ones.

On the perceptual side, relational theories such as those of the Gestalt school, have been less concerned with developmental/linguistic effects (Koffka's "Growth of the Mind" (1924) notwithstanding). They have been concerned, rather, with demonstrating the ubiquity of relational responses.

> "Reviewing our observations .... we find that everywhere the aspect of sensory experience depends upon the

properties of stimuli in their mutual interrelationship."
(Köhler, 1930, p 96).

Gestalt theory, however, embraces the more complex questions of relational responding such as those concerning "levels" of psychological operation. Most Gestaltists distinguish, for example, between the <u>determinants</u> of experience (these are the "mutual interrelationships") and their <u>phenomenal products</u> (these are what Koffka (1924) describes as "configurative phenomena".) Thus, relations are in Koffka's terms "silent" and "not normally experienced in the sensory field" (Kohler, 1930 p 166).

Recently, a much simplified version of this perceptual/relational theory has been advanced by Bryant (1973b) who argues that "relative codes" are fundamental even to the operations of very young children. "Absolute" codes, by contrast, are slow to develop and even in the adult do not make for accurate judgments. The "novel" aspect of his position, as he puts it, is the mechanism which he proposes is used by children to "get round" the difficulties encountered by their having only "relative codes" at their disposal.

> "If a child who uses primarily a relative code is shown a single object, he will not ordinarily be able to remember much about for instance its absolute size, because he has no effective way of recording it. In fact, if he depends on registering relations, the only way he can remember its actual size, to compare it to other sizes, is to relate it to the size of some constant background feature (if one is available) and then to use this relation inferentially." (p 12)

In making this statement Bryant assumes two "facts" about the behaviour of young children, for which he has no direct evidence. Firstly, he assumes (without adequate reference to the "literature" on this matter) that children are unable to make single, "absolute" judgments. His argument that this inability "can be overcome" by inferential mechanisms rests however on data from transposition and other experiments which have not directly tested the subject's ability to make single stimulus judgments.[+] Nowhere does Bryant indicate evidence to show that, when asked to do so, children cannot make appropriate judgments of single stimuli under conditions where no obvious basis for an "inference" is available. Secondly, Bryant implies that relative codes allow a child to operate as competently at an abstract logico-linguistic level as at a perceptual (and concrete) one, by failing to acknowledge that there may be qualitative differences between the two - as outlined, for example, by Werner (1948).

> "..... two separate phases are often observable in the thought processes of comparison. The first is the formation of a perceptual relationship - the relation between two parts is grasped in a certain configuration. The second is the derivative abstract form of the relationship as expressed in a verbally constituted judgment." (p 221)

[+] These studies, furthermore, do not normally establish by instruction or other means the criteria (i.e. "relative" or "absolute") by which the subject is expected to judge the test stimuli. Where such instructions have been given (Zeiler and Salten, 1967; Riley et al, 1966) it has been found, in fact, that "absolute" instructions reduce transposition.

If Bryant had investigated the "verbally expressed judgments" of children (independently from his "inference" tests), he would surely have encountered some of the limitations even on their "concrete" comprehension indicated by investigators in this area (Clark, 1973; Donaldson and Wales, 1970; Donaldson and Lloyd, 1966). An immediate question raised by these findings is: by what criteria does a verbally expressed judgment indicate an "understanding" of relational terms? Mere utterance is, as Wales and Campbell (1970) point out, no criterion for understanding:

> "It is a matter of considerable practical and theoretical importance to explore the child's developing ability to comprehend and appropriately produce these kinds of constructions and not to assume that this linguistic ability is available to him simply because he uses these expressions in certain 'spontaneous' situations.

Thus, a second "fact" assumed by Bryant is that young children's use of relational terms indicates true comprehension. As pointed out in Chapter Two the argument which appears to justify this assumption is circular. Without an independent criterion for comprehension, therefore, there is no telling just how rudimentary the child's understanding is. In an attempt to clarify this matter it was decided to provide subjects with two simple tasks of "concrete" comprehension - one simultaneous and one successive. In the simultaneous case, subjects were required to categorise an array of sticks of different sizes into "big" ones, "small" ones, "taller" ones, etc. In the successive case subjects were asked to judge individual stimuli derived from the simultaneous array.

EXPERIMENT 3

SUBJECTS

The subjects were 20 children (10 boys and 10 girls) with mean age 4 years 9 months and a range of 4.3 to 5.6. They all attended primary or nursery schools in Edinburgh.

STIMULI

The stimuli were wooden cylindrical sticks of diameter 1.5 cm. and they differed in length on a ratio scale of 1:1.1. Their sizes are shown in Table 12.

TABLE 12

Stick No	1	2	3	4	5	6	7	8	9	10	11	12
Size (in cms)	5.3	5.8	6.4	7.0	7.7	8.5	9.4	10.3	11.3	12.5	13.7	15.1

DESIGN

All subjects were presented with two sets of sticks in order to assess the extent to which they could use relational terms to reflect the sizes of the particular set of sticks in front of them. The sets were overlapping in size range in order that stimuli common to both could be used as a yardstick of the change in the judgment of particular sticks wrought by changes in the stimulus set as a whole. Subjects were allocated randomly to two groups, A (10 subjects) and B (10subjects). The stimulus sets presented to these groups are shown in Table 13 (over).

The experimental phases are shown in Table 14 (over).

PROCEDURE

The experiment was conducted in four phases which were run (as far as possible) on four consecutive days.

TABLE 13

Group A	Set 1.	Stick No:	1 2 3 4 5 6 7 8
		Colour:	Red (Subjects 1 - 5) Green (Subjects 6 - 10)
	Set 2.	Stick No:	5 6 7 8 9 10 11 12
		Colour:	Green (Subjects 1 - 5) Red (Subjects 6 - 10)
Group B	Set 1.	Stick No:	5 6 7 8 9 10 11 12
		Colour:	Red (Subjects 1 - 5) Green (Subjects 6 - 10)
	Set 2.	Stick No:	1 2 3 4 5 6 7 8
		Colour:	Green (Subjects 1 - 5) Red (Subjects 6 - 10)

TABLE 14

Phase	I	II	III	IV
Stimulus Set	1	1	2	2
Stimulus Presentation	Simultaneous	Successive	Simultaneous	Successive
Criteria for Judgment	Little Small Smaller Short Shorter Middle-sized Big Bigger Tall Taller Long Longer	Small/Big or Middle-sized Long/Short or Middle-sized	See Phase I	See Phase II

Phase I

Stimuli were arranged randomly in a horizontal array supported in an upright position on a white wooden base. The subject was asked to indicate, by pointing, which sticks he thought were e.g. the big ones, followed by the bigger ones, the tall ones, the taller ones, the long ones, the longer ones, the short ones, the shorter ones, the small ones, the smaller ones, the little ones and the middle-sized ones. This was repeated twice. The 12 instructions were always given in random order and the arrangement of the sticks was changed before each instruction block.

Phase II

Subjects were given one rehearsal block of instructions with Set 1 as in Phase I. The stimuli were then removed from the subject's view and re-presented singly and in random order, standing upright on a small white wooden base. The subject viewed each stimulus and was asked by the experimenter: "Is that a big one, a small one or a middle-sized one?". A second run in a different random order was given, this time using the question: "Is that a short one, a long one or a middle-sized one?". The first two runs were repeated using a different random presentation each time. The order of size terms in each question was randomly varied across trials. Half the subjects in each group started with a big/small/middle-sized run and the other half started with a long/short/middle-sized run.

Phase III

Subjects were presented with Set 2 and the procedure was followed as in Phase I.

Phase IV

Subjects were rehearsed with one run on Set 2 and the procedure followed as in Phase III.

All stimuli were viewed against a white background. Subjects were intermittently told that they were "doing well" but no specific reinforcement was given. All responses were recorded on a videotape recorder for subsequent analysis.

COMPUTATION OF RESULTS

As all subjects showed high internal consistency across runs and across sessions, the results in the following section are tabulated and computed on the basis of totals obtained for each subject across repeated runs.

RESULTS

Table 15 a. and b. shows the frequency distribution of choices made by both groups of subjects in response to the 12 types of question asked during simultaneous presentation of the sticks.

TABLE 15. Frequency of Choice during Simultaneous Presentation

a. Group A (N=10)

Stick No:	1	2	3	4	5	6	7	8	9	10	11	12	Total
Set 1													
Little	38	24	18	08	04	00	00	00					92
Small	38	38	23	09	07	00	00	00					115
Smaller	39	35	19	11	03	01	00	00					108
Short	24	25	24	17	17	09	01	01					118
Shorter	28	27	25	18	15	06	03	01					123
Middle-sized	11	13	20	26	22	15	05	01					113
Big	00	02	04	10	14	27	35	37					129
Bigger	01	02	03	09	17	25	33	36					126
Tall	03	02	03	09	14	19	35	34					119
Taller	03	03	04	09	10	23	32	33					117
Long	05	03	05	07	12	29	35	36					132
Longer	01	01	02	08	16	25	29	31					113
Set 2													
Little					36	32	23	08	03	02	01	00	105
Small					36	29	20	07	02	02	03	02	101
Smaller					36	29	20	06	01	02	01	02	97
Short					26	25	26	16	09	04	02	02	110
Shorter					22	26	21	13	06	04	04	03	99
Middle-sized					13	15	21	21	20	12	06	01	109
Big					02	01	01	03	15	26	36	34	118
Bigger					02	03	02	09	19	25	33	34	127
Tall					01	01	07	07	12	18	31	32	109
Taller					04	02	04	07	12	16	35	34	114
Long					00	02	01	07	18	22	32	36	118
Longer					03	00	05	05	13	24	32	32	114

b. Group B (N=10)

Stick No:	1	2	3	4	5	6	7	8	9	10	11	12	Total
Set 1													
Little					38	30	19	14	06	05	01	01	114
Small					40	29	21	14	07	03	00	00	114
Smaller					39	30	25	16	07	04	00	00	121
Short					21	20	20	15	12	07	06	07	108
Shorter					23	25	20	16	10	06	07	05	112
Middle-sized					17	16	23	22	13	07	05	05	108
Big					00	00	00	03	12	19	39	39	112
Bigger					00	00	00	03	08	13	30	39	93
Tall					06	04	06	04	11	17	30	34	112
Taller					05	06	05	05	11	17	29	33	111
Long					00	00	01	04	09	15	32	39	100
Longer					00	00	00	02	07	14	31	39	93
Set 2													
Little	40	30	24	19	13	09	03	01					139
Small	40	31	22	13	09	07	02	01					125
Smaller	40	35	24	15	13	08	03	01					139
Short	22	24	20	16	13	14	13	07					129
Shorter	23	21	15	12	08	07	13	08					107
Middle-sized	15	14	17	21	19	15	07	09					127
Big	01	00	00	03	05	12	31	38					90
Bigger	00	00	03	03	05	12	25	38					86
Tall	08	09	08	06	04	09	22	31					97
Taller	09	08	07	04	04	09	22	33					96
Long	02	01	03	05	08	11	25	39					94
Longer	00	00	00	03	06	12	25	40					86

Table 16 a. and b. (over) shows the frequency distribution made by both groups of subjects in response to the two types of question asked during successive presentation of the sticks.

TABLE 16. **Frequency of Choice during Successive Presentation**

a. Group A (N=10)

Stick No:	1	2	3	4	5	6	7	8	9	10	11	12
Set 1												
Small	20	14	13	06	01	00	01	00				
Middle-sized	00	05	07	13	15	07	02	01				
Big	00	00	00	01	04	13	17	19				
Short	13	11	09	05	03	05	00	01				
Middle-sized	03	05	08	15	13	04	02	01				
Long	02	02	01	00	04	11	18	18				
Set 2												
Small					15	11	03	00	01	00	00	00
Middle-sized					05	08	14	11	05	02	02	00
Big					00	01	03	06	15	17	18	20
Short					15	11	07	02	01	00	00	01
Middle-sized					04	08	12	11	05	04	01	00
Long					00	00	01	07	14	16	19	19

b. Group B (N=10)

Stick No:	1	2	3	4	5	6	7	8	9	10	11	12
Set 1												
Small					11	10	07	02	02	01	00	00
Middle-sized					08	08	11	14	13	04	02	00
Big					00	01	02	03	04	15	18	20
Short					08	07	01	04	05	05	03	03
Middle-sized					09	13	16	14	07	06	01	01
Long					00	00	02	02	07	09	16	16
Set 2												
Small	14	14	11	09	05	01	00	00				
Middle-sized	04	05	08	10	10	08	05	01				
Big	01	00	00	00	03	08	15	19				
Short	09	08	05	09	06	04	04	02				
Middle-sized	09	10	12	09	12	10	04	02				
Long	02	02	03	02	02	06	12	16				

Inspection of Table 15 suggests that the data may be compressed into three categories: B (comprising responses to big, bigger, tall, taller, long and longer), S (comprising responses to small, smaller, short, shorter, and little) and M (middle-sized). This grouping is confirmed by a Friedman Two-Way Analysis of Variance which shows high concordance of the rank distributions within the categories B and S ($p < 0.001$, $df = 7$).

Figure 3 (over) shows the distribution curves for B, S and M.[+]

Table 17 a. and b. shows the relative proportions of responses to B, S and M for the stimuli which were common to both sets.

TABLE 17. Overall Proportion of Responses to B, S and M for Sticks 5, 6, 7, 8 (Combined) (Set 1 and Set 2)

a. Simultaneous Presentation

Category	S		M		B	
	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2
Group A	.07	.51	.25	.41	.68	.08
Group B	.51	.21	.43	.33	.06	.46

b. Successive Presentation

Category	S		M		B	
	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2
Group A	.06	.43	.28	.45	.65	.11
Group B	.33	.14	.60	.34	.06	.51

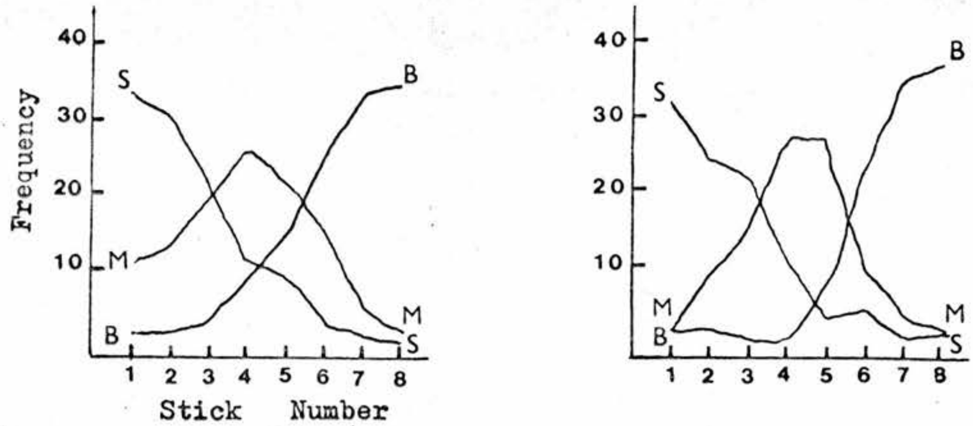
[+] For B and S these distributions are plotted as the average frequency across the various questions comprising that category (5 or 6 in the simultaneous case; 2 in the successive case). M is plotted as the actual (overall) frequency for the simultaneous case and as the average (overall) frequency across to 2 question types in the successive case.

FIGURE 3 RESPONSE DISTRIBUTIONS FOR CATEGORIES B, M AND S.+

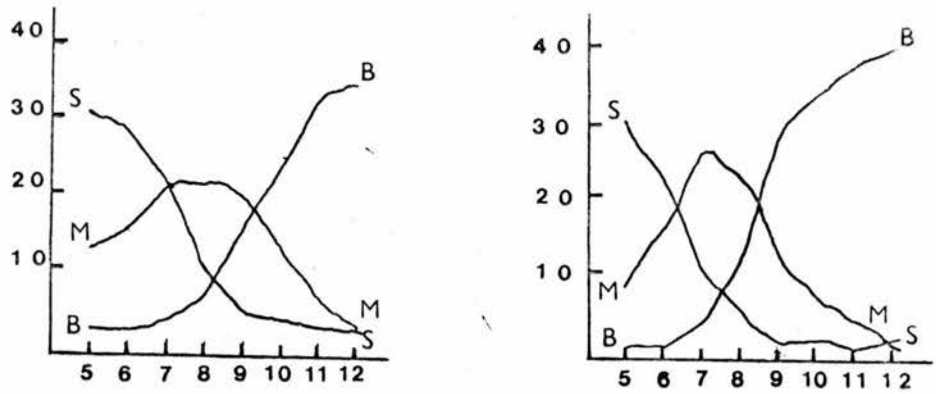
GROUP A

SIMULTANEOUS SUCCESSIVE

Set 1

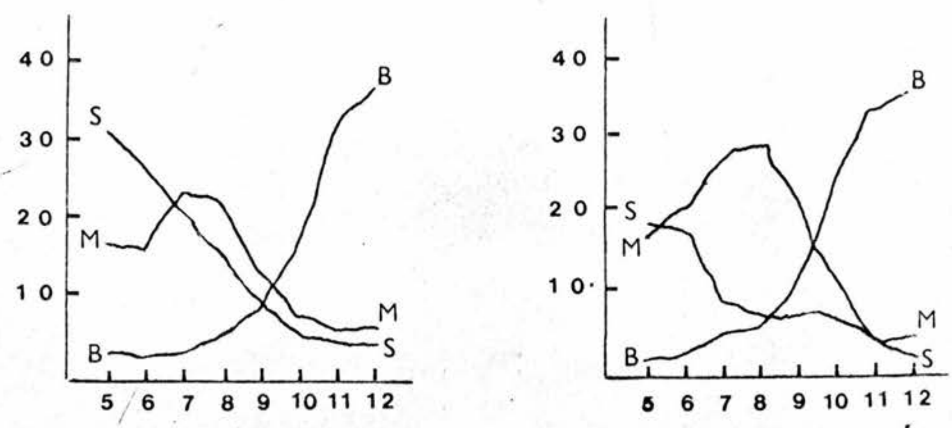


Set 2

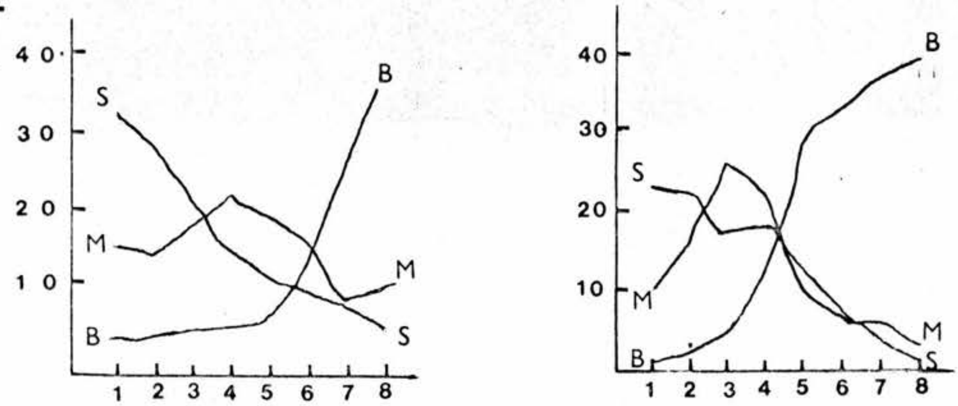


GROUP B

Set 1



Set 2



\+ The Spearman Rank Correlation Coefficients obtained between simultaneous and successive distributions are significant at the 1 percent level.

Figure 4. (over) compares the response distributions for the terms small, big, short and long across simultaneous and successive conditions.[+]

DISCUSSION

The results show clearly:

a) that the stimuli were judged relative to the set in which they were embedded irrespective of their actual size on the length 'continuum'; and

b) successive judgments were made as competently as simultaneous judgments.

Thus the "values" or "adaptation level" for e.g. "big" and "small" which derived from simultaneous stimulus presentation carried over to the successive case. It is hardly necessary to assume, however, as Bryant does (1973,b,p12) that such successive judgment is achieved by the use of deductive inferences which result from the co-ordination of successive sets of background or framework relationships. On the contrary, a notion such as Helson's (1964) which postulates that an internal referent is produced by the pooled or weighted average of past and present stimulation could handle the results adequately. Thus, stimuli above the adaptation level are deemed "big" and those below it are judged as "small". Unsurprising as these results might be in the context of A.L. theory, the interesting question which remains concerns the factors which allow the subject to isolate one set of values from another such that the pooled average is not affected or distorted by the inclusion of those stimuli which lie without the set or collection. One clue to such isolation is given in the study of weight judgment by Brown (1953) which shows the impact of categorical

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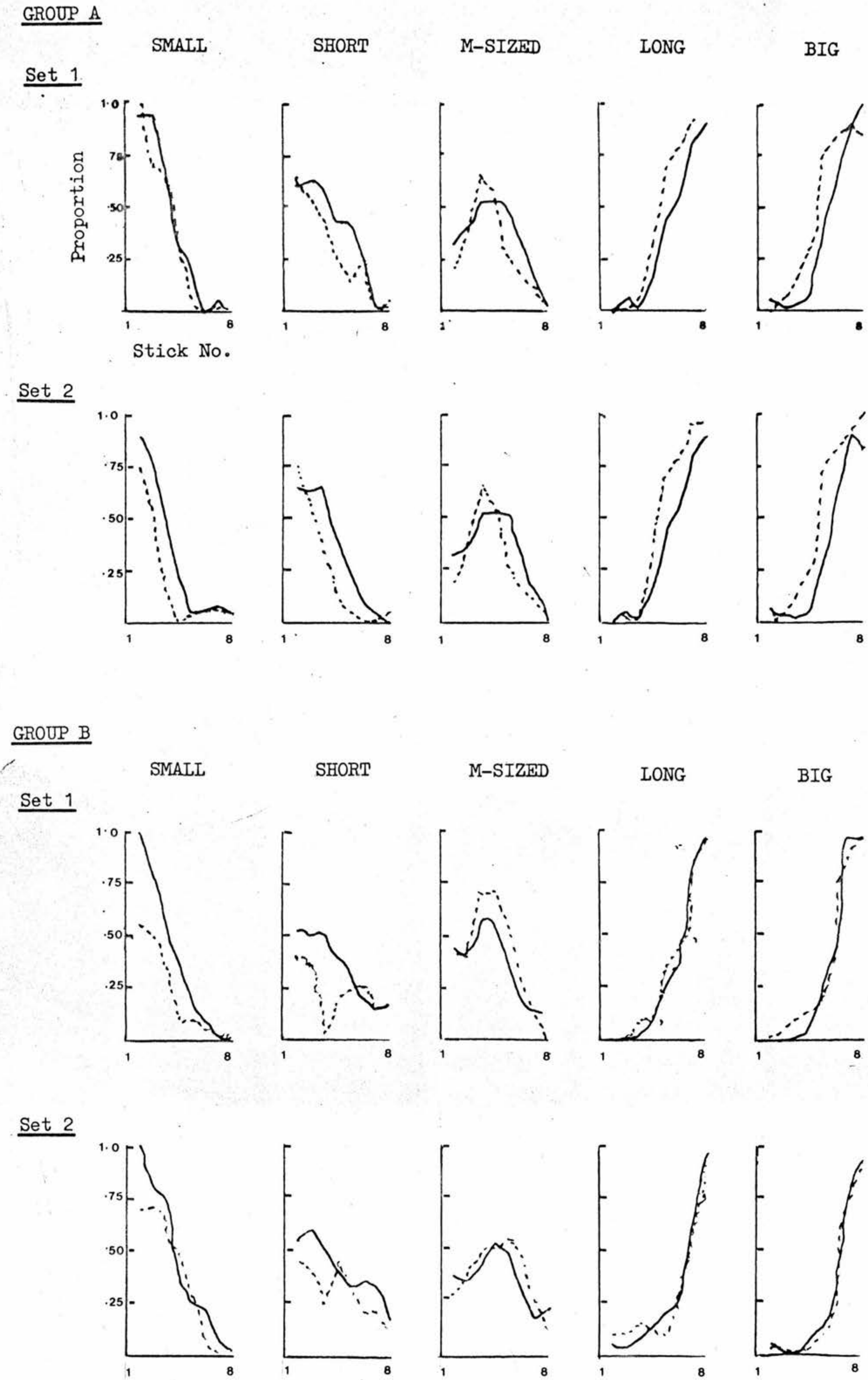
[+] These distributions are plotted as a proportion of the total response that could possibly be made to each stick for a given size term.

FIGURE 4 COMPARISON OF SIMULTANEOUS (——) AND SUCCESSIVE (----) RESPONSE DISTRIBUTIONS



criteria in insulating stimulus values of one category from those in another. Brown found that when a subject was casually asked to move a heavy tray "out of the way" it had no effect on the adaptation level presumably because it was considered to lie outside the stimulus series. In the case of subjects in Experiment 3 both the colour of the sticks and their spatio-temporal isolation (as sets) could have produced set independence. For a young, and ostensibly "concrete" subject, however, we might expect stimulus proximity (both spatial and temporal) to be the most important single determinant of the identity of a collection. Piaget (1964) cites an example of this in which a five-year-old subject divided a set of red circles into small ones and large ones; when presented with blue circles he divided these also into small and large but added them into his collection of red circles.

In the next experiment therefore, the question is asked : does the child add his collections (i.e. both red and green) together, when the members of each are intermixed and presented in a random, successive order?

EXPERIMENT 4

SUBJECTS

The same subjects were used as in Experiment 3.

STIMULI

The s timuli were those used in Experiment 3.

DESIGN

The main features of the design are depicted in Table 18.

TABLE 18.

Phase	I	II
Stimulus Set	1 & 2	1 & 2
Stimulus Presentation	Successive	Simultaneous

The same criteria for simultaneous and successive judgments were used as in Experiment 3.

PROCEDURE

The experiment was conducted in two phases carried out on the two consecutive days immediately following Phase IV of Experiment 3. The 16 sticks from Sets 1 and 2 were presented singly and in random order as in the successive presentation phases of Experiment 3. However, to minimise the load on the subject only one run of each question type was given.

Phase II

The sticks were randomly arranged in a horizontal array of 16 and three runs were given as in the simultaneous phases of Experiment 3.

Responses were recorded as in Experiment 3.

RESULTS

Table 19 a. and b. shows the frequency distribution made by both groups of subjects in response to the two types of question asked during combined successive presentation of both sets of sticks.

TABLE 19. Frequency of Choice during Combined Successive Presentation

a. Group A (N=10)

Stick No:	1	2	3	4	5	6	7	8	9	10	11	12
Small	08	10	08	09	04	01	02	00				
					09	01	01	00	00	00	00	00
Middle-sized	02	00	02	01	06	08	06	04				
					00	08	07	05	04	01	01	00
Big	00	00	00	00	00	01	02	06				
					01	01	02	05	06	09	09	10
Short	09	07	04	07	06	02	03	00				
					05	03	02	02	00	00	00	01
Middle-sized	00	02	04	03	03	07	07	03				
					02	07	05	04	02	00	00	00
Long	00	00	01	00	01	01	00	07				
					02	00	03	04	08	10	10	09

TABLE 19.

b. Group B (N=10)

Stick No:	1	2	3	4	5	6	7	8	9	10	11	12
Small					04	01	01	02	00	01	00	00
	07	09	08	06	04	02	02	00				
Middle-sized					04	08	06	03	01	00	01	00
	03	01	02	02	05	05	06	02				
Big					02	01	03	05	10	08	09	10
	00	00	00	01	01	03	02	07				
Short					04	02	04	02	02	02	02	01
	05	04	05	05	03	05	03	03				
Middle-sized					05	06	04	03	02	01	00	00
	04	05	05	04	07	03	05	03				
Long					01	02	02	05	06	07	08	09
	01	01	00	01	00	02	02	04				

Table 20 a. and b. (over) shows the frequency distribution of choices made by both groups of subjects in response to the 12 types of question asked during the combined simultaneous presentation of both sets of sticks.

TABLE 20. **Frequency of Choice during Combined Simultaneous Presentation**

a. Group A (N=10)

Stick No:	1	2	3	4	5	6	7	8	9	10	11	12
Little	25	24	13	14	09	05	06	01				
					04	01	03	00	02	00	01	01
Small	27	25	17	11	08	05	02	00				
					05	04	03	01	00	02	02	02
Smaller	26	25	17	13	09	00	01	01				
					05	03	03	02	01	01	02	02
Short	17	14	10	12	14	10	08	06				
					05	07	04	06	04	01	03	04
Shorter	15	13	09	06	09	10	07	05				
					07	08	04	04	03	02	02	01
Middle-sized	00	02	05	07	11	12	14	07				
					10	09	12	10	05	02	01	00
Big	00	00	01	00	00	01	00	02				
					02	00	02	03	11	19	29	25
Bigger	01	00	01	00	00	01	00	02				
					02	01	06	05	12	17	25	27
Tall	00	01	00	00	01	00	03	03				
					01	01	06	05	10	14	25	26
Taller	00	00	01	00	00	00	03	04				
					02	00	05	04	11	14	25	25
Long	00	02	01	00	03	03	02	01				
					01	01	05	07	11	19	25	26
Longer	00	01	00	00	01	01	03	03				
					02	02	04	08	15	19	27	15

b. Group B (N=10)

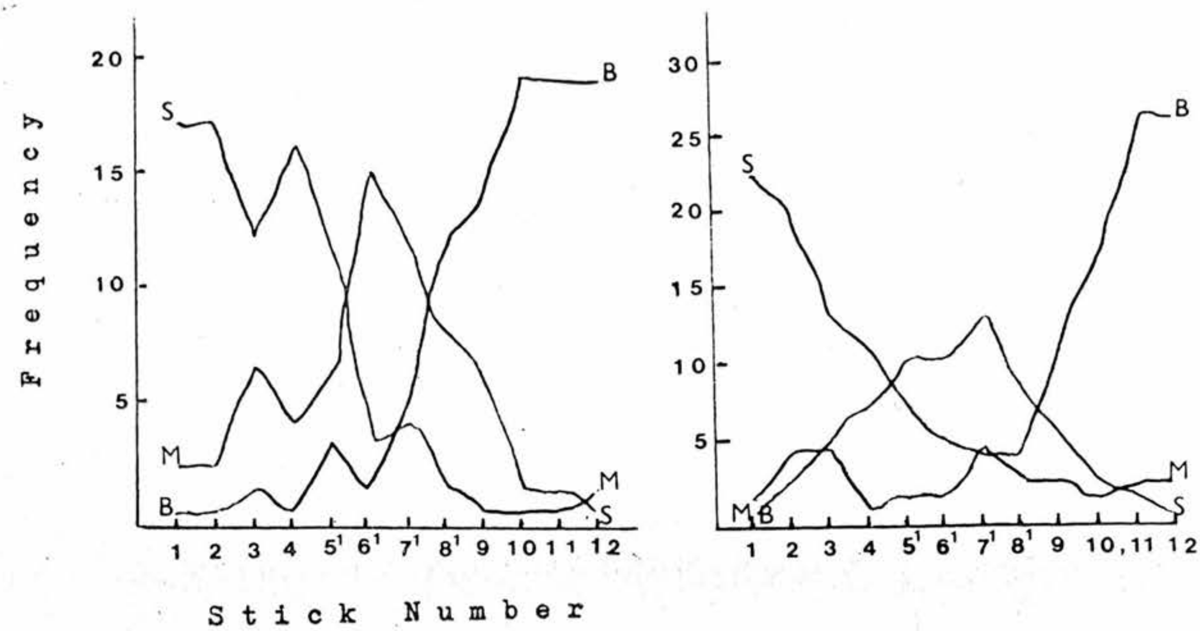
Stick No:	1	2	3	4	5	6	7	8	9	10	11	12
Little					06	06	06	04	02	03	02	02
	29	19	18	15	10	06	05	04				
Small					09	08	07	06	04	03	01	01
	30	26	22	15	10	09	05	05				
Smaller					09	08	09	06	05	03	03	02
	26	23	20	15	13	09	06	08				
Short					05	09	07	05	06	03	04	05
	16	14	11	13	08	08	06	08				
Shorter					04	05	07	08	08	07	07	08
	17	15	16	14	11	08	11	07				
Middle-sized					10	11	12	11	08	05	05	06
	09	08	06	10	09	13	09	06				
Big					02	02	02	04	12	17	24	29
	02	02	02	02	02	02	02	06				
Bigger					00	00	02	06	12	14	24	30
	00	00	00	00	00	03	02	02				
Tall					02	03	03	00	08	14	17	24
	04	06	06	03	04	03	02	04				
Taller					02	01	01	02	05	12	16	25
	03	04	05	03	02	02	01	03				
Long					01	02	03	03	10	14	19	27
	01	01	01	02	01	02	03	05				
Longer					00	00	01	02	11	19	20	30
	00	00	00	00	00	00	01	01				

To aid comparison, the data are combined (as in Experiment 1) into S, M and B. Figure 5 (over) shows the frequency distribution curves for combined successive and combined simultaneous presentation of both sets of stimuli, for both groups. To improve clarity the responses to the overlapping sticks are represented on the graphs as the mean response for each pair of identical stimuli. The frequencies are plotted as before.

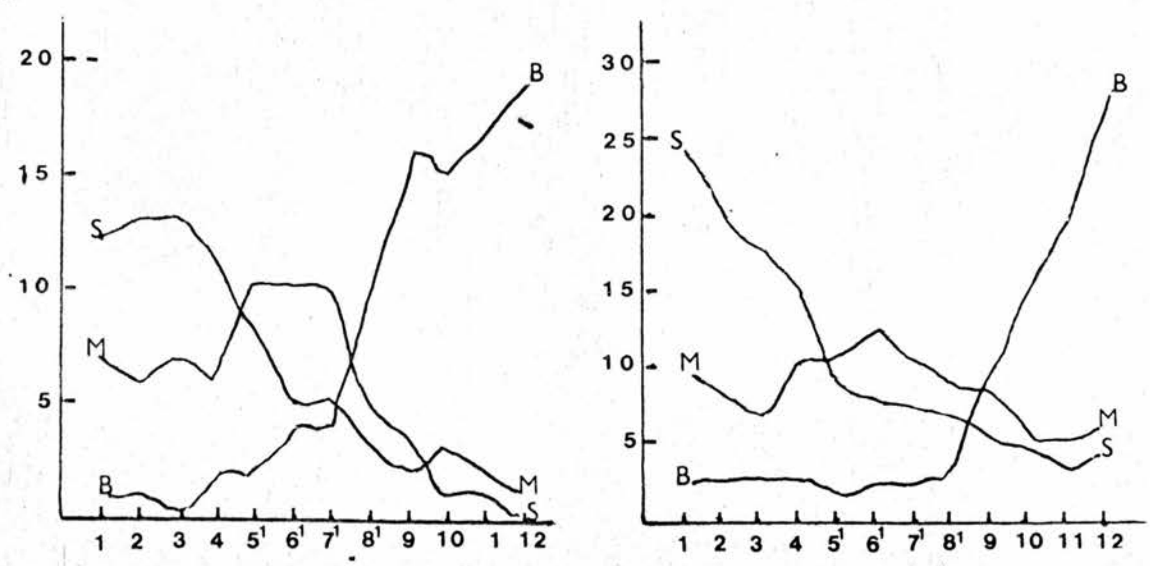
FIGURE 5 RESPONSE DISTRIBUTIONS FOR CATEGORIES B, M AND S.

SUCCESSIVE SIMULTANEOUS

GROUP A



GROUP B



A Kendall Coefficient of Concordance (Siegel, 1956) shows that the choice distributions are equivalent for both groups and also for both types of presentation for all three categories (X^2 sig. at $p < 0.001$ $df = 11$).

Table 21 shows the relative choice proportions for the stimuli which were common to both sets.

TABLE 21. Overall Proportion of Responses to B, S and M for Sticks 5, 6, 7, 8 (Combined) (Set 1 and Set 2)

a. Successive Presentation

Category	S		M		B	
	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2
Group A	.23	.32	.56	.48	.20	.20
Group B	.28	.28	.48	.46	.42	.39

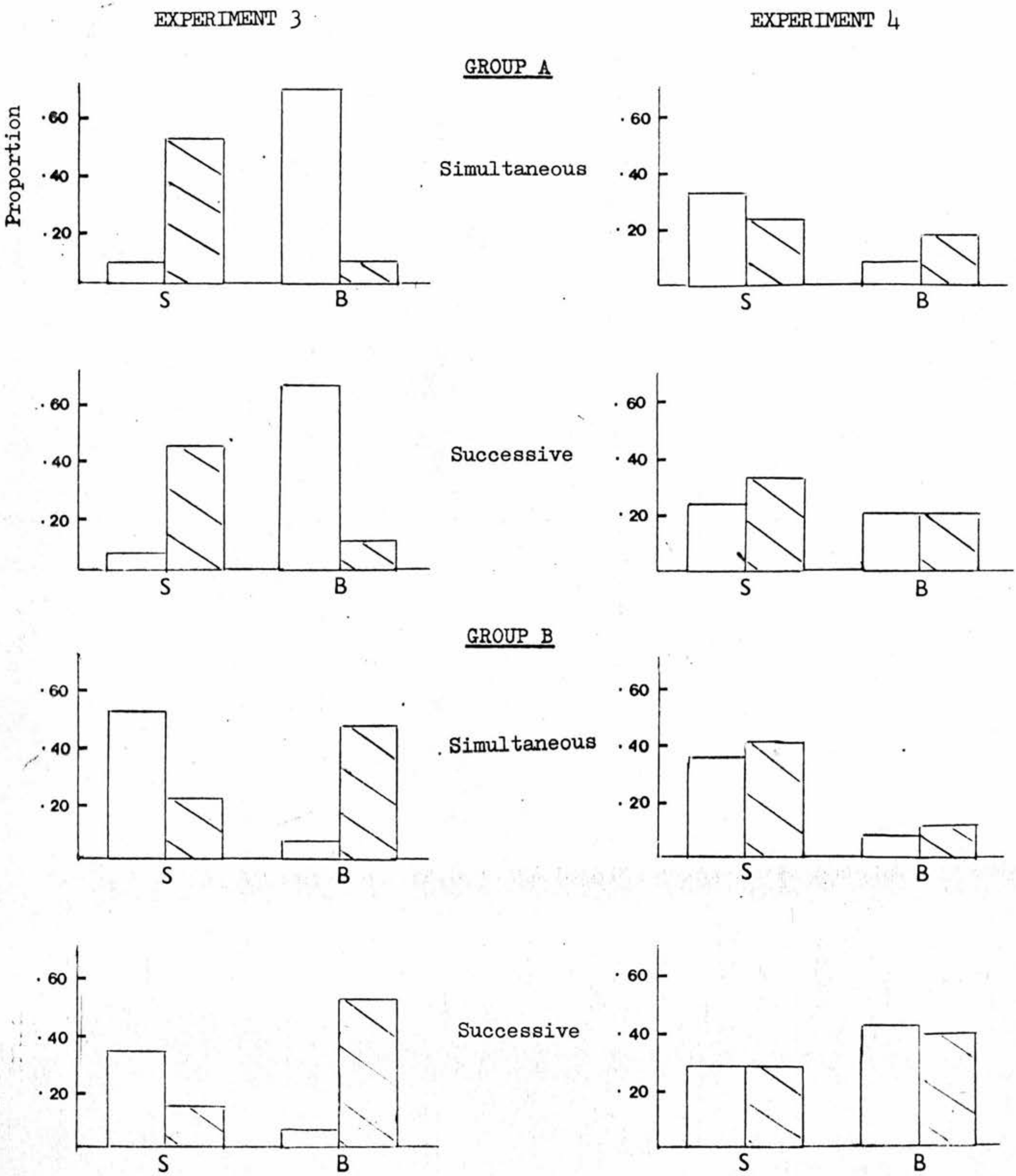
b. Simultaneous Presentation

Category	S		M		B	
	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2
Group A	.32	.23	.60	.59	.08	.17
Group B	.35	.40	.56	.48	.09	.12

In Figure 6 (over) these proportions are compared with those from Experiment 3.

Figure 7 (p 69) compares the choice proportions for big, small, long and short across simultaneous and successive presentation.

FIGURE 6 COMPARISON OF RESPONSE DISTRIBUTION FOR S AND B TO OVERLAPPING STIMULI 5, 6, 7 AND 8



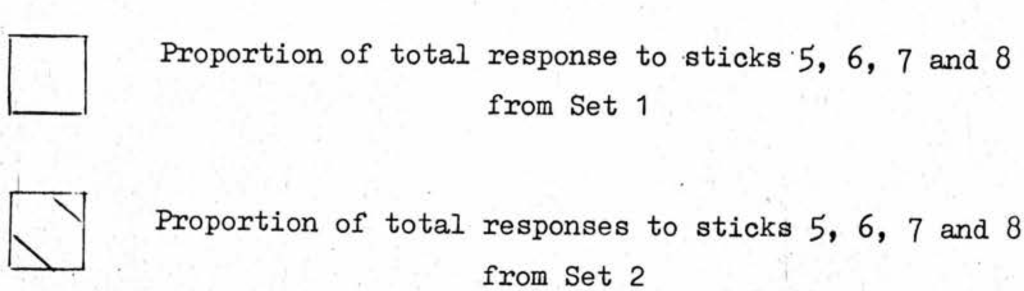
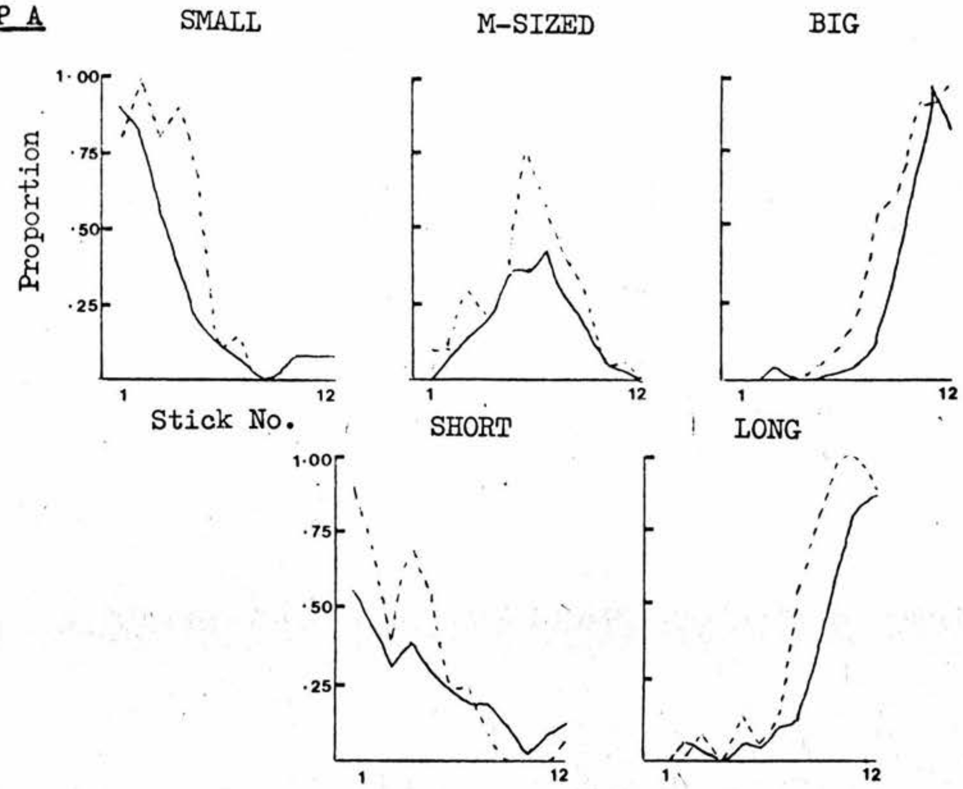
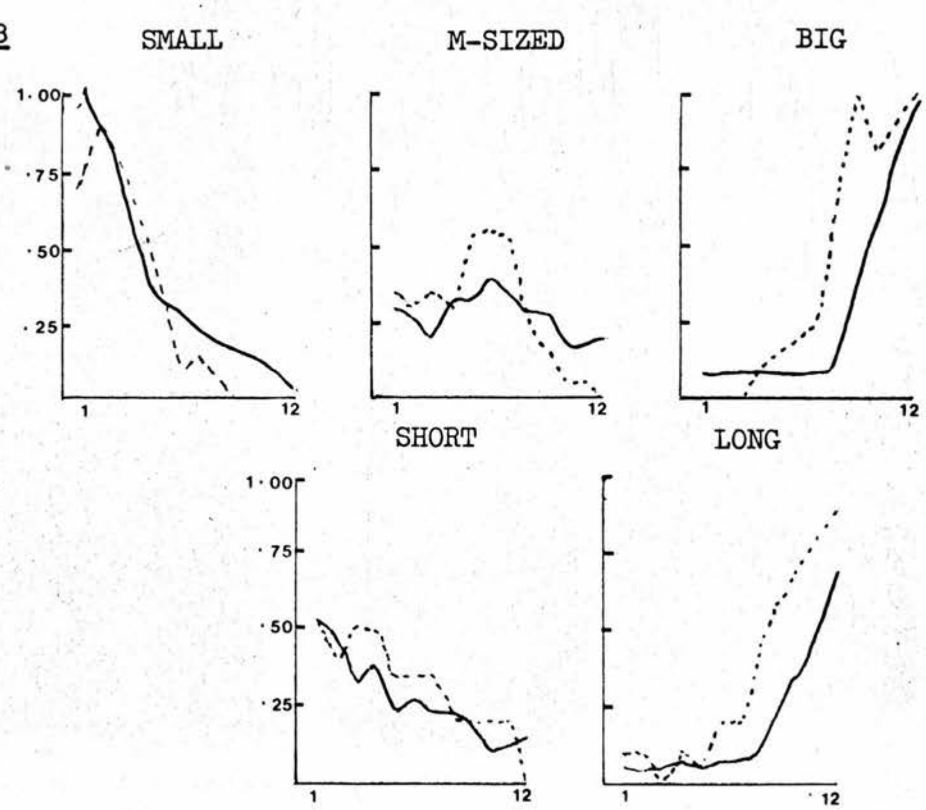


FIGURE 7 COMPARISON OF SIMULTANEOUS (——) AND SUCCESSIVE (----) RESPONSE DISTRIBUTIONS

GROUP A



GROUP B



DISCUSSION

The results show that the subjects abandoned their previous "labels" and treated the stimuli as a new, combined collection even when they had only been presented successively. This suggests that they are not only competent but also, to a certain degree, flexible in making successive judgments.

Piaget (1964) mentions two possible criteria by which a collection may be connected - perceived similarity and functional belonging. In his illustrations, the spatial groups were the child's own product. However, others have suggested that spatial proximity (and from the above results it seems that temporal proximity and succession also ought to be considered) is an important determinant of what will be seen to be connected. Lashley (1960) reports that a spider monkey failed on a matching task unless the discriminanda were actually touching one another. In Piaget's own examples, spatial proximity and functional belonging seem to be closely related in the child's mind: "they're all for the dining room", "all that is for the kitchen" (1964 p 41). Much of Piaget's evidence in fact suggests that up until the age of six or seven, spatial proximity is a critical factor in determining what a child will consider as a collection. He cites, for example, the case of Dei (5.5), "When the experimenter jumbles the circles together after Dei has subdivided them into red and blue he reacts as follows: 'Do they still go together?' - 'No, they don't go together because they've been disarranged.' " (1964, p 215)

Rather than disarrange the collections of sticks in the present experimental context it was decided to introduce new items into the collection which, if categorized separately, should receive size labels independently of those given to the sticks.

EXPERIMENT 5

SUBJECTS

The subjects were those used in Experiments 3 and 4.

STIMULI

In addition to those stimuli used in Experiment 4, 10 new stimuli were used - five 'dolls' and five 'clowns'. Their sizes are shown in Table 22.

TABLE 22

	Doll No.					Stick No	Clown No.				
	1	2	3	4	5	1 ... 12	1	2	3	4	5
Size (cms)	3.3	3.6	4.0	4.4	4.8	5.3...15.1	16.6	18.2	20	22	24.3

DESIGN AND PROCEDURE

Subjects were presented with stimulus Sets 1 and 2 along with the dolls and clowns.

These were presented randomly in a horizontal array and subjects were required to make size judgments as in the procedure of the simultaneous phases of Experiments 3 and 4. Three runs were given.

RESULTS

Table 23 a. and b. (pp 73 - 74) and Figure 8 (p 75) (plotted as before) show the response distributions for all stimuli.

TABLE 23. Frequency of Choice during Combined Simultaneous Presentation with Dolls (D) and Clowns (C)

a. Group A (N=10)

Stimulus No:	D1	D2	D3	D4	D5	1	2	3	4	5	6	7	8	9	10	11	12	C1	C2	C3	C4	C5
Little	26	21	23	20	20	18	21	15	07	08 02	06 02	00 01	03 02	00	01	01	02	00	01	00	00	00
Small	22	22	20	18	20	18	20	18	08	04 07	05 03	04 01	03 01	03	01	03	03	00	00	00	01	01
Smaller	22	21	21	19	19	18	20	14	08	05 06	07 02	00 02	03 02	03	01	02	02	01	02	01	00	02
Short	12	13	11	15	14	08	15	10	05	06 06	06 10	06 09	09 07	02	01	02	01	02	01	01	01	01
Shorter	15	14	15	16	15	09	12	07	05	05 07	08 06	07 07	06 06	02	00	01	01	00	01	00	00	00
Middle-sized	04	03	03	04	05	05	06	08	09	09 08	10 09	09 12	05 10	05	04	06	02	05	02	01	01	00
Big	01	00	00	01	00	01	01	00	00	00 02	02 01	00 01	01 03	08	14	16	19	19	22	21	26	25
Bigger	00	00	00	00	00	00	00	00	00	00 00	00 02	00 00	02 01	04	09	14	13	16	22	23	26	25
Tall	00	00	01	00	01	02	01	01	01	01 01	01 00	03 03	05 03	05	11	12	15	12	17	18	24	24
Taller	00	01	00	00	00	00	00	01	00	00 01	01 03	02 04	04 03	06	05	08	10	13	17	17	18	24
Long	00	01	00	00	01	00	01	00	01	00 02	01 00	01 01	01 03	04	08	12	13	16	23	24	24	25
Longer	00	01	00	00	00	00	00	00	02	01 01	02 01	01 00	01 01	02	07	09	12	20	20	21	21	26

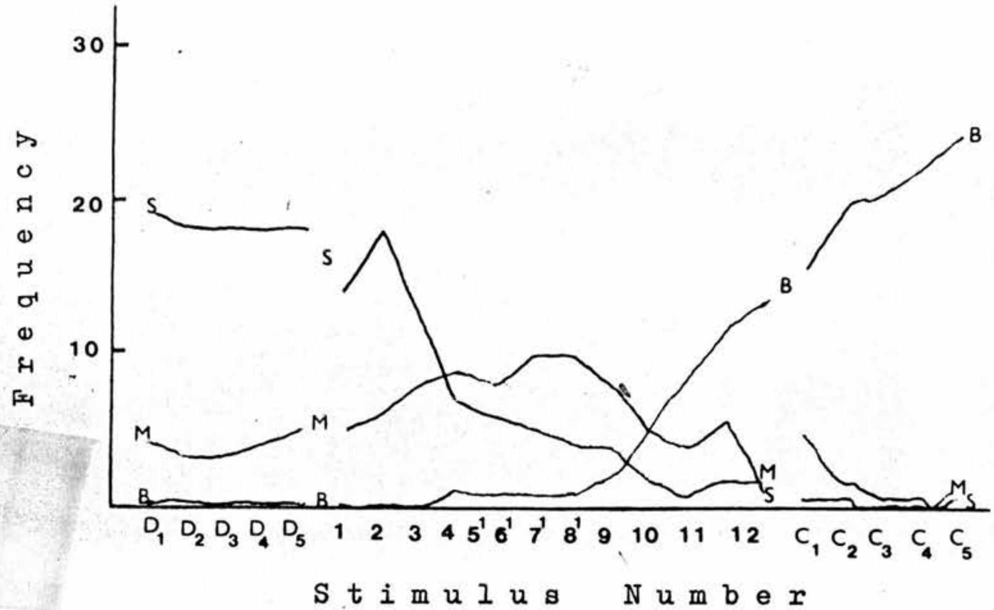
TABLE 23. Frequency of Choice during Combined Simultaneous Presentation with Dolls (D) and Clowns (C)

b. Group B (N=10)

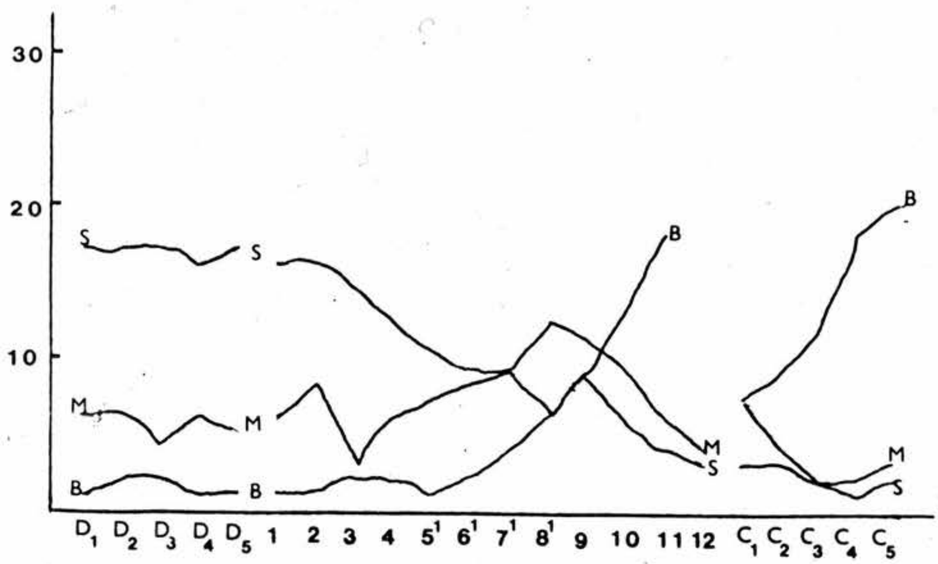
Stimulus No:	D1	D2	D3	D4	D5	1	2	3	4	5	6	7	8	9	10	11	12	C1	C2	C3	C4	C5
Little	21	20	20	18	20	19	15	13	10	07 09	04 08	06 05	04 04	05	04	03	01	04	00	00	01	00
Small	20	19	21	19	20	20	21	18	15	13 13	08 12	08 08	06 09	07	06	03	02	03	02	01	01	01
Smaller	19	18	17	16	17	20	18	13	10	06 07	07 06	05 06	02 03	01	01	01	01	03	02	01	01	01
Short	13	14	13	13	13	09	15	12	11	08 12	10 13	11 07	08 09	08	05	04	03	06	08	06	01	01
Shorter	14	14	15	14	13	13	12	13	16	13 13	12 12	14 14	08 08	10	12	07	08	01	01	03	03	05
Middle-sized	06	06	04	06	05	06	08	03	06	10 04	09 06	08 10	09 14	11	09	06	04	07	04	02	02	03
Big	00	01	01	00	00	00	00	00	00	00 01	01 02	03 00	02 01	06	10	14	20	07	10	13	18	20
Bigger	01	01	01	01	01	01	01	03	02	03 02	04 02	02 03	03 02	08	13	15	22	10	10	15	20	21
Tall	02	02	04	02	03	02	02	05	05	00 02	00 01	02 02	03 02	06	05	10	16	06	07	08	18	19
Taller	03	03	03	03	03	03	04	05	03	01 01	01 02	01 02	03 02	05	07	12	15	06	08	12	16	20
Long	00	01	00	00	00	00	00	00	00	02 01	02 01	03 00	03 01	06	08	18	18	05	07	10	17	21
Longer	00	01	00	01	01	01	01	00	00	02 02	01 03	01 02	04 02	06	10	17	19	10	11	12	19	21

FIGURE 8 RESPONSE DISTRIBUTIONS FOR CATEGORIES B, M AND S.

GROUP A



GROUP B



DISCUSSION

The results of Experiment 5 show that, apart from very slight evidence of a categorical "break" between stick 12 and Clown 1, the "dolls", "clowns" and sticks were treated as a single collection. Thus it appears that spatio-temporal proximity is a more important factor in grouping than is categorisation via object properties per se.

It would appear, therefore, that the profile which emerges is fully concordant with Piaget's conception of the "pre-operational" child who classifies according to spatial configurations ("graphic collections"), but cannot co-ordinate the relations of intension and extension as demanded by a classificatory "logic" (Piaget, 1964). Furthermore, as the following demonstration will show, this disability persists even when familiar and well-defined classes are referred to by the experimenter.

DEMONSTRATION

SUBJECTS

Two subjects were used. They were both girls aged 4.6.

PROCEDURE

Subjects were given a set of verbally-presented questions concerning the relative sizes of animals. The animal names used were "mouse" and "lion". The size terms used were "baby", "daddy", "bigger", "smaller", "small", "big" and "wee". In Part A of the procedure questions were given to establish the child's understanding of these size terms with respect to a single animal class, e.g. "Which is the 'baby' one - a small lion or a big lion?". In Part B questions were given to establish the extent to which the size terms could be appropriately used across the two classes, e.g. "Which is bigger - a 'baby' lion or a "daddy" mouse?".

Care was taken to avoid, as far as possible, an answer based on an acoustic "echo" of part of the question as in, for example, "Which is smaller - a small mouse or a big lion?". For this reason the terms "wee", "baby" and "daddy" were introduced - to provide some variation.

Care was taken also to check that answers were not consistently based on a "primacy" or "recency" effect, i.e. an "echo" of the first or last stated alternative in the question.

All responses were recorded by a tape recorder.

RESULTS

The full protocols of both subjects are reproduced below. Nine of the seventeen Part B questions were considered to be particularly "crucial" in testing the subject's ability to "co-ordinate" at the verbal level. These are marked with an asterisk.

PROTOCOLS

Subject 1. Eileen Ann

Part A

1. Question: "Which is the 'baby' one - a wee mouse or a big mouse?"
   Answer: "A wee mouse."

2. Q. "Which is the bigger one - a 'daddy' lion or a 'baby' lion?"
   A. "A daddy lion."

3. Q. "Which is the 'baby' one - a wee lion or a big lion?"
   A. "A wee lion."

4. Q. "Which is the bigger one - a 'daddy' mouse or a 'baby' mouse?"
   A. "A daddy mouse."

Part B

1. Q. "Which is the bigger one - a 'daddy' lion or a 'baby' mouse?"
   A. "A daddy lion."

2.* Q. "Which is the 'baby' one - a wee lion or a big mouse?"
   A. "A wee lion."

3.* Q. "Which is the bigger one - a 'daddy' mouse or a 'baby' lion?"
   A. "A daddy mouse."

4. Q. "Which is the 'baby' one - a wee mouse or a big lion?"
   A. "A wee mouse."

5. Q. "Which is the bigger one - a wee mouse or a big lion?"
   A. "A big lion - mouse!"

6.* Q. "Which is the smaller one - a big mouse or a wee lion?"
   A. "A wee lion."

7. Q. "Which is the smaller one - a 'daddy' lion or a 'baby' mouse?"
   A. "A baby mouse."

8. Q. "Which is the smaller one - a big lion or a wee mouse?"

A. "A wee mouse."

9.* Q. "Which is the smaller one - a 'baby' lion or a 'daddy' mouse?"

A. "A baby lion."

Subject 2. Julie

Part A

1. Q. "Which is bigger - a 'daddy' mouse or a 'baby' mouse?"

A. "A daddy mouse."

2. Q. "Which is the 'baby' one - a big lion or a wee lion?"

A. "A wee lion."

3. Q. "Which is bigger - a 'daddy' lion or a 'baby' lion?"

A. "A daddy lion."

Part B

1.* Q. "Which is the 'baby' one - a big mouse or a wee lion?"

A. "A wee lion."

2.* Q. "Which is the bigger one - a 'daddy' mouse or a 'baby' lion?"

A. "A baby lion."

3.* Q. "Which is the 'baby' one - a big mouse or a wee lion?"

A. "A big mouse."

4. Q. "Which is the bigger one - a 'daddy' lion or a 'baby' mouse?"

A. "A daddy lion."

5. Q. "Which is the baby one - a big lion or a wee mouse?"

A. "A wee mouse."

6. Q. "Which is the bigger one - a wee mouse or a big lion?"

A. "A big lion."

7.* Q. "Which is the smaller one - a wee lion or a big mouse?"

A. "A wee lion."

8.* Q. "Which is the bigger one - a wee lion or a big mouse?"

A. "A big mouse."

SUMMARY OF RESULTS

Seven mistakes were made out of the nine "crucial" questions. (Eileen Ann; Part B questions 2, 3, 6 and 9; Julie: Part B questions 1, 7 and 8). It seems, therefore, that the "correct" answers were arrived at accidentally, for both subjects showed a consistent strategy of repeating the phrase which "echoed" the relational term used twice in the question (irrespective of the class of animal to which it referred).

DISCUSSION

Considered in the context of Experiments 3, 4 and 5, the main implication of the above study is that relational comprehension at the logico-linguistic level should be sharply distinguished from "concrete" comprehension. This view is suggested by two findings. The first is that none of the logico-syntactic factors that Hunter (1957), for example, isolated in adult verbal reasoning tasks appear to consistently produce the predicted effects in four- and five-year-old children. That is, subjects in Experiment 2 who were given heterotropically presented tasks did not appear to suffer any disadvantage (as measured by acquisition scores and rejection rate) over subjects in Experiment 1 who were given isotropic presentation of the information. That this is a general feature of "concrete" solutions is suggested by a study carried out by Glick and Wapner (1968) who, using subjects ranging in age from seven to eighteen years, found that in "concrete" tests of transitivity using e.g. dolls as stimuli, "there is virtually no difference between the heterotropic and isotropic forms of the concrete test, but that performance in the verbal test is markedly better in the isotropic condition". Furthermore, apart from the failure to demonstrate verbal reasoning at all in young children, the results of Experiment 2 indicate that their grasp of verbal relational terms is too limited even to permit elementary "reversibility" (Piaget, 1964) as shown by their failure to recover "reciprocal" information.

Secondly, the linguistic or purely lexical effects indicated by Clark (1969, a) as a significant factor in verbal reasoning tests, show little evidence of appearing in a concrete context. Clark (1969, a; 1970) has argued that the negative or "marked" terms of an antonymous pair are more complex and require more operations of reference than do unmarked terms. He demonstrated this in the context of adult verbal reasoning tests by showing that syllogisms involving marked terms take longer to solve than those involving only unmarked terms.

No such asymmetry (at least as far as the "pointing" data indicate) is obvious in Experiments 3, 4 and 5[+] - and evidence that marking effects exist at all for children of this age is none too convincing. The only published study[++] cited by Clark (1970) which shows ostensible evidence for marking effects in the context of a "concrete" test given to young children is one carried out by Donaldson and Wales (1970). These investigators looked at the pre-school child's responses to questions involving superlative and comparative size terms. Comprehension was measured by the "correct" selection of one out of a set of four stimuli. In particular, the data from the "comparative" tests (i.e. terms such as those used in the above experiments) was poor support for the existence of lexical marking effects in children. This data is reproduced below. The figures refer to the frequency of "correct" choices of a stimulus.

[+] Nor were such effects apparent in Experiment 2.

[++] Clark (1970) also cites a Senior Honours Thesis by Tashiro, Stanford University.

TABLE 24.

(Item)	(1)		(2)		(3)		(4)	
	Bigger:	Wee-er	Longer:	Shorter	Thicker:	Thinner	Higher:	Lower
	14	13	12	14	11	10	13	10
(Item)	(5)		(6)		(7)		(8)	
	Taller:	Shorter	Fatter:	Thinner	Bigger:	Wee-er	Longer:	Shorter
	10	7	10	7	7	5	10	9

(reproduced from "On the Acquisition of some Relational Terms" in Hayes, J.R., Cognition and the Development of Language, 1969, pp 235-268).

A number of factors make these results hard to evaluate. Firstly, it can be seen that while the "biggest" stimulus is described multi-dimensionally by six different terms, the "smallest" (i.e. the "marked" term) is given less emphasis by being described by only four different terms. Secondly, it appears from the description of the experiment (Wales and Campbell, 1970) that the "positive", unmarked terms were emphasised further by being referred to first in every trial. Thirdly, three of the items in the table ought to be discounted from the overall analysis on the grounds:

a) that one of them was ambiguous (Item (7)). This item involved showing subjects four stimuli whose height and width covaried inversely; and

b) that items (5) and (6) used "familiar" stimuli (pictures of men, as distinct from the blocks and sticks used for the other items) which may have biased the responses in favour of a more "familiar" description.

If these three items are discounted, the assymmetry in the responses can be seen to be very slight: 56 correct "marked" responses as opposed to 60 correct "unmarked" responses. These comments apart, Wales and Campbell (1970) themselves point out: "A number of design factors complicate the interpretation of the results of this test." Overall, therefore, this study appears to provide slender evidence for "marking" effects in young children.

In summary, therefore, the balance of evidence reported both here and elsewhere seems to support the distinctions made by several investigators concerning different "levels" of psychological operation. As Glick and Wapner (1968) point out:

> "Whether phrased in terms of the relation between the "perceptual" and the "conceptual" (Werner, 1940, 1957), the "iconic" and the "symbolic" (Bruner, 1966) or the "concrete" and the "formal" (Inhelder and Piaget, 1964), it is generally conceded that there are structural differences between the two types of thought and that they appear at different points in development."

There must now be serious doubt as to whether the version of the five-term series as adapted by Bryant and Trabasso (1971) taps symbolic mechanisms at all. Certainly it can be said that cues of a non-symbolic origin feature in the training context. There are almost certainly spatial cues at work and the "accidental" effects of serial learning cannot be discounted either. One additional factor which now appears to be highly significant is the feedback variable. Whereas in Bryant and Trabasso's 1971 study it was claimed that absence of feedback made no difference to performance of four- and five-year-olds (Bryant and Trabasso, 1971, Experiment 2), a more recent study, using the same paradigm, (Riley and Trabasso, 1974) has led to a quite different conclusion: "The relatively poorer performance has consistently been in those conditions where feedback is only linguistic." (Trabasso, 1975) Concrete feedback, therefore, appears to be a major factor and, as the results of Experiment 3, reported above, show, four-year-olds can "internalise" such information extremely effectively.

In the next section of the thesis, therefore, new attempts are described to establish strongly transitive choice profiles under conditions of distinctive and immediate sensory feedback.

CHAPTER FOUR

Although Bryant and Trabasso (1971) imply that feedback, when it is both verbal and sensory is equivalent in producing a transitive choice profile, the subsequent findings of Trabasso and his co-workers suggest to the contrary. Riley and Trabasso (1974) found weaker transitivity in a group of subjects trained without benefit of immediate visual feedback and this finding has been extended and amplified by Trabasso (1975) who compared four groups (linguistic feedback with no spatial aid; linguistic feedback with spatial aid; visual feedback with no spatial aid; visual feedback with spatial aid) and found that presence of sensory feedback was the most critical factor in successful training.

However, Trabasso et al, in demonstrating the importance of sensory feedback, have seemingly reduced the transitivity "phenomenon" in young children to something quite trivial. For, as the results reported in Chapter Three show, four-year-olds can "place" individual sizes in a series even under successive conditions of test. Thus subjects given exposure (albeit serially) to all (five) physical values of the series may have been able to "read" these values off with respect to some simple "iconic" representation of them. And this representation would demand neither "integration" of pairwise information into a linear series (as Trabasso, 1975, would suggest) nor co-ordination of the crucial premises at the time of tests of transitivity.

The possibility remains, however, that such feedback may only be necessary to instill into young subjects, some adequate comprehension of the relationships contained within the pairs without requiring complete sensory knowledge of the series as a whole; i.e. if the same (two) physical values were used repeatedly to provide feedback within each training pair such that no one stimulus came to be uniquely identified with a particular physical value, would choices be transitive under these conditions? If they were, then such transitivity as may be found could not be due to any "direct" memory of the physical values used in the feedback condition.

The experiments reported in this Chapter test this neglected possibility.

EXPERIMENT 6

SUBJECTS

The subjects were 20 schoolchildren (10 boys and 10 girls) with a mean age of 6.5 and a range of 5.3 to 6.8.

STIMULI AND APPARATUS

Subjects were trained and tested in a W.G.T.A. The stimuli were painted tobacco tins of diameter 7 cms. and height 2.75 cms. "Heavy" tins were filled with lead shot, "Light" tins were empty. Five coloured wooden trays (27 cms. x 15 cms.) were used for displaying the stimuli. These were green, red, yellow, white and blue.

DESIGN

The subjects were divided into a Verbal group and a Non-Verbal group. This was done to permit an evaluation of the additional encoding process which might be expected to occur in the Verbal condition, when sensory feedback is translated into verbal labels. Feedback was provided by weight differences between the stimuli used in training. However, only two weight values were used. Weight was selected to provide feedback that was immediate and easily sensed by the subject. Furthermore, weight can be referred to without subjects expecting to <u>see</u> actual weight differences. (This overcomes a problem encountered in the course of Experiment 1.)

The main features of the design are depicted in Table 25 (over).

PROCEDURE

The Non-Verbal subjects were rewarded by finding a coloured counter in a cavity under the appropriate tin.+ They were encouraged to collect as many of these counters as possible, which were then placed in a glass jar beside the subject.

+ The details of the entire Non-Verbal trial by trial procedure are given in Experiment 9, pp 118/119.

TABLE 25. Scheme of Training Paradigm

NON-VERBAL (10 Subjects)									
Series Identification		A	B	B	C	C	D	D	E
Pair		1		2		3		4	
Weight Order	(5 Subjects)	L	H	L	H	L	H	L	H
	(5 Subjects)	H	L	H	L	H	L	H	L
Colour+ e.g.		Y	B	B	R	R	W	W	G
Rewarded Stimulus e.g.			B		R		W		G

VERBAL (10 Subjects)									
Series Identification		A	B	B	C	C	D	D	E
Pair		1		2		3		4	
Weight Order	(5 Subjects)	L	H	L	H	L	H	L	H
	(5 Subjects)	H	L	H	L	H	L	H	L
Colour+ e.g.		W	R	R	G	G	B	B	Y
Question asked		Which L?		Which L?		Which L?		Which L?	
		Which H?		Which H?		Which H?		Which H?	

L = Light. H = Heavy. Y = Yellow. B = Blue. R = Red. W = White. G = Green.

+ Colour was counterbalanced according to a Latin Square Design.

The Verbal subjects were asked either "Which is the light one?" or "Which is the heavy one?" on any one trial. Both types of question were asked for all four pairs. Heavy/light questions were counterbalanced across trials. After each question the tray was pushed forward and the subject was asked to pick up the named tin and see if he was right.

Correction trials were given for both Verbal and Non-Verbal subjects.

Subjects were randomly assigned to one series of colour pairings (see Table 25) and one of the five trays. Subjects were trained in the following way.

<u>Phase I</u>

Subjects were trained to a performance criterion of 9/10 correct on each pair in serial order from Pair 1 to Pair 4. Subjects were rejected if they required more than 30 trials on any one pair. As each pair was introduced, both Verbal and Non-Verbal subjects were asked the following questions:

"What are those?"

"What colours are they?"

"Pick them up. Do they feel the same?"

(If, "no") "Why not?"

Subjects who could not name all the colours correctly or who could not feel any difference between the tins were rejected.

<u>Phase II</u>

Subjects were given "runs" which consisted of four trials on each pair in serial order from Pair 1 to Pair 4. This continued until a performance criterion was reached of two successive runs correct (i.e. 32 trials). Subjects were rejected if they required more than 200 trials to reach criterion.

Phase III

Subjects were given runs as before but the number of trials per pair was reduced to two. Subjects were rejected if they required more than 200 trials.

Phase IV

Subjects were given six runs of one trial per pair.

Phase V

Subjects were given runs consisting of one trial per pair in random order. They were required to reach a performance criterion of six successive runs correct (24 trials). Subjects were rejected if they required more than 200 trials to reach criterion.

Right-left location of the tins was randomly varied across trials. Approximately 25 trials were given per session and sessions were run as far as possible on consecutive days.

Testing

Subjects' performance on the random pairs was maintained at at least 90% correct on each pair over a given session. The "critical" test pair BD was randomly embedded amongst the training pairs not more than twice per session. Non-Verbal subjects were given no differential reward, i.e. tins were either both heavy or both light in accordance with the subject's previous training. Responses to both stimuli were rewarded. Verbal subjects were given no feedback on test items. Six test trials were given for each pair. For Verbal subjects the type of question asked was randomised across trials with the constraint that three trials for any test item involved the question "Which is the light one?" and three trials involved the question "Which is the heavy one?".

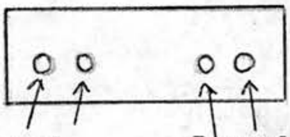
Trial times were recorded during the testing phase of the experiment by means of a signal generator (played into a tape recorder) which the experimenter activated by pressing a small hand-button. A trial was considered to commence when the door of the W.G.T.A. was fully uplifted and was considered to end immediately after the subject had made his response. The times were subsequently measured by a reaction time device.

AIDS TO TRAINING

Shortly after commencement of the experiment, the proportion of rejected to successful subjects led to a rather pessimistic view of the child's ability to succeed on this task. It was decided therefore to provide additional aids in training based on the finding that spatial layout can enhance the performance of young children on this type of task (Riley and Trabasso, 1974). It was decided to create a situation where spatial separation of the pairs may reduce proactive interference across pairs but where no correct solution was possible on the basis of the layout alone (see e.g. The Bryant and Trabasso "box" artefact).

A long stimulus tray was introduced with two reward cavities placed at either end (see Figure 9).

FIGURE 9.



Reward Cavities for pairs AB and CD

Reward Cavities for pairs BC and DE.

Subjects were transferred to the long tray if they failed to meet criterion at some point during training on the short tray. Transferred subjects were re-trained from Phase II and rejection criteria were used as before. All test items were administered on the short trays. In all, ten subjects (five from each group) required this spatial aid in order to complete training. [Comparisons between the results of "long tray" and "short tray" subjects are made in the appendix. To assess the extent of a possible advantage afforded by the long tray, "short tray" subjects were subsequently re-trained on the long tray. The results of this re-training are also reported in the Appendix.]

RESULTS AND COMMENTARY

TRAINING

TABLE 26. Number of Subjects Rejected (Mean Age)

	No. Tested	No. Rejected
Non-Verbal	10 (6.2)	3 (6.2)
Verbal	10 (6.7)	4 (5.10)

Four out of the seven rejected subjects failed during Phase I.

As only three out of the 27 children actually failed on the concurrent phase of training, it seems that subjects found the training task in the above experiment easier than in Experiments 1. and 2. reported in Chapter Two. This was probably due to some or all of the factors which were deliberately aimed at achieving training success. These were: (i) higher mean age of subjects, (ii) the use of concrete feedback, and (iii) the provision of a spatial aid.

Table 27 shows the error profile for the first and final phases of training. Mean reaction times are shown in parenthesis for Phase V.

TABLE 27. Percentage of Total Error (Mean R.T. in M.Secs)

	Phase I				Phase V			
	AB	BC	CD	DE	AB	BC	CD	DE
Non-Verbal	55	15	22	08	02	41	40	17
R.T.s	--	--	--	--	2480	2720	2840	2320
Verbal	29	27	29	15	04	31	59	06
R.T.s	--	--	--	--	3377	3882	3777	3174

A serial position effect was observed during the final phase of training, with more errors and longer reaction times associated with the middle pairs (See also Riley and Trabasso, 1974, Experiment 1).

TESTING

TABLE 28. Binary Choice Profiles for Verbal and Non-Verbal Groups

	NON-VERBAL (N=10)					VERBAL (N=10)			
	B	C	D	E		B	C	D	E
A	.98	.70	.57*	.80	A	.97	.52*	.72	.77
B		.98	.70	.88	B		.97	.77	.75
C			.98	.78	C			1.00	.87
D				.98	D				.98

* Non-significant on a Binomial Test ($p < 0.01$)

The results of both groups show a clear transitive profile overall and significant biases are obtained on both sets of "BD" scores.

DISCUSSION

Are we to assume on the basis of the above results that these children are solving the problem by means of a deductive inference? Certainly, the evidence is consistent with the idea that the solution is achieved by co-ordinating two pieces of information - that, for example, B is heavier than C, and that C is heavier than D.

There are alternative ways in which the problem might be solved, however. One such alternative originates in the field of animal perceptual research (McGonigle and Jones, 1975, 1977). These investigators have produced evidence which they claim substantiates the view (e.g. of Garner, 1962, 1974) that the perception of a single stimulus is determined either by the (stimulus) set in which it (currently) features and/or the set from which it is presumed to come, i.e. a set which is inferred inductively. Such a view has also received recent support from Ford and Olson (1975) who suggest that children in the process of generating descriptive sentences learn to see objects in the larger context provided by their former experiences, i.e. in terms of inferred alternatives. As these authors point out:

> "It is reasonable to suggest that it is the description of objects in terms of larger and larger sets of inferred alternatives that gives rise to the general coding of objects we call common names."

Applied to the problem of transitivity, such notions of inferred set have led to the development of a sampling model reported by McGonigle and Chalmers (1977)+ which is radically at odds with the

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+ This study is reported in the next Chapter.

co-ordinate theory of Bryant and Trabasso, and assumes instead that transitive choices result from single binary decision making. The model is described by McGonigle and Chalmers as follows:

"A set BCD, for example, affords three subsets, BC, CD and BD. If a decision is based exclusively on the interrogation of any one subset, and if we assume (in the absence of information to the contrary) that each subset is interrogated equally often, then it is possible to compute the choice proportions to each of the constituent members of the triad BCD on a given trial. If, therefore, the probability of selecting any one of the subsets as a basis for choice is 0.33 (approximately) we can thus predict an overall choice proportion of 0.33 in the case of C (assuming absolute preference for C over B). D has two reference subsets, CD and BD. In the case of subset CD (making the same assumptions as above) the choice proportion predicted for D will be approximately 33%. In the case of subset BD, however, we need assume no consistent preference for either B or D. On the 33% of all occasions on which these comparisons are made, the subject may select either one equally often. In this case, the overall probability of choosing D would rise by a further 16% (with roughly 16% of all choices going to B). Thus we might predict the approximate choice proportions for all three stimuli in the set BCD as follows: B = 0.17, C = 0.33 and D = 0.50.

"In a two-choice situation, of course, where B is presented in conjunction with D, C would have to be "inferred" as a referent (an assumption in common with the co-ordination model, some theories of perception, and of transitivity and a reasonable one given the duplicate relationship of C with B and D). In this instance the choice proportions attributable to C when actually present will now add to the overall proportions for D (as half of them will rule out responses to B, the other half will confirm D directly). Thus the probability values for BD in a two-choice situation will now be: B = 0.17, D = 0.83.

"In the case of comparisons involving an endpoint value, however, (either A or E), fewer subsets will be at chance levels of choice (taking as a total population all 10 triadic permutations of the 5 term series A, B, C, D and E); thus the projection for the average transitive choice proportion is 0.98."

It is clear from the above that the binary sampling model makes specific predictions concerning the choice distributions that would be obtained if three stimuli (for example, B, C and D) are actually presented to the subject for choice, following establishment of strong preferences within subsets BC and CD. In such triadic tests, the binary sampling model predicts both a "reduced" transitive effect and specifies, in addition, the choice profiles for each of the triads in turn. By contrast, no such predictions are afforded by the co-ordination theory, particularly when all the relevant test items are present in the immediate perceptual field. A direct test of these positions was made in the following experiment.

EXPERIMENT 7

SUBJECTS

The subjects were those used in Experiment 6.

STIMULI AND APPARATUS

The stimuli and apparatus were identical to those used in Experiment 6. Additional trays (of colours red, blue, white, green and yellow) with three (instead of two) cavities were introduced for use with the Non-Verbal group in testing.

DESIGN

The design features of Experiment 6 were maintained.

PROCEDURE

Training

Subjects were re-trained (if re-training was necessary) to their previous performance of at least 90% correct within a single session.

Testing

Six of the total set of ten triads were administered to subjects across four separate sessions. These were ABC, BCD, CDE, ABD, BCE and BDE. In the first two sessions, the triads ABC, BCD and CDE were randomly interspersed amongst the random "runs" of the four training pairs, until six presentations had been given on each triad. In sessions 3 and 4, the triads ABD, BCE and BDE were administered in the same way. The location of each stimulus in every triad was counterbalanced. For Verbal subjects, the type of test question asked, i.e. "Which is the heavy one?" and "Which is the light one?", was randomised within triads with the constraint that three of each type of question was given for each. No differential feedback was given for the Non-Verbal group and no feedback was given at all for the Verbal group on triadic tests. All triads were presented on "short" trays.

RESULTS

The results are summarised in Table 29.

TABLE 29. **Triadic Choice Profiles**

Verbal

TRIADS	CHOICE PROJECTION			OBTAINED (Each row based on 30 observations)		
	* ⟶			* ⟶		
ABC	.00	.33	.67	.06	.54	.40
BCD	.17	.33	.50	.22	.19	.59
CDE	.00	.33	.67	.06	.22	.72
ABD	.00	.50	.50	.13	.54	.33
BCE	.00	.33	.67	.18	.23	.57
BDE	.17	.17	.60	.20	.33	.47
Average Distribution	.06	.33	.61	.14	.34	.52
TRIADS	**CHOICE PROJECTION**			**OBTAINED (Each row based on 30 observations)**		
	⟵		*	⟵		*
ABC	.67	.33	.00	.58	.28	.14
BCD	.50	.33	.17	.58	.34	.08
CDE	.67	.33	.00	.78	.15	.07
ABD	.66	.17	.17	.60	.22	.18
BCE	.67	.33	.00	.57	.34	.09
BDE	.50	.50	.00	.42	.48	.10
Average Distribution	.61	.33	.06	.59	.30	.11

* Arrows refer to the direction of choice required by the question: ⟶ = A ⟶ E; ⟵ = A ⟵ E.

TABLE 29.

Non-Verbal

TRIADS	CHOICE PROJECTION			OBTAINED (Each row based on 60 observations)		
ABC	.00	.33	.67	.08	.28	.64
BCD	.17	.33	.50	.20	.23	.57
CDE	.00	.33	.67	.17	.15	.68
ABD	.00	.50	.50	.10	.43	.47
BCE	.00	.33	.67	.03	.47	.50
BDE	.17	.17	.66	.28	.20	.52
Average Distribution	.06	.33	.61	.14	.29	.57

DISCUSSION

Triadic tests provide the basis for discrimination between what might appear to be equally competent positions with respect to the two-choice transitivity data (see Levelt, 1970). For the co-ordination model must predict that, when confronted with the three stimuli crucial to co-ordination in two-choice tests, i.e. BCD, the subject must now select D with at least the same frequency as in the case of the B versus D comparisons (where C is alleged to be first inferred inductively+ and then used in a deductive operation to produce the solution). By contrast, the binary choice model as proposed by McGonigle and Chalmers (1977) assumes that only the inductive inferential stage (to infer 'C' when B versus D comparisons are involved) is both a necessary and sufficient condition to guarantee a transitive solution. Given the binary assumptions of this model, it is quite clear that frequency of selecting D will change radically from the two-choice case, B v D, to the triadic case, B v C v D (as no co-ordination on serial choice operations are anticipated by the model).

As the results show, the choice profiles which emerge in the triadic tests are fully compatible with the predictions made by this model for each of the triads in turn.

The implications of such results are consistent moreover with other research findings in a child-developmental context. In a study by Ford and Olson (1975), for example, it was claimed that inductive

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+ Bryant does not make this point explicit but any explanation which would suggest that C is a deductively inferred referent would be circular.

inferences are basic to the descriptive operations of children of a similar age to those used in the experiments described above. In Ford and Olson's study, four-, five- and seven-year-old children were required to describe objects varying in colour, size, shape and decorative markings. From their investigations, Ford and Olson concluded "that children's descriptions reflect the contrasting alternatives in the situation as a whole, not the immediate context of alternatives". Compatible also with the findings from Experiment 7 is Ford and Olson's observation that even when all the relevant information is given perceptually, children cannot utilise it all to generate exhaustive descriptions of the stimuli placed in front of them. This deficit in the utilization of information which is 'given' perceptually is confirmed, further, by Lunzer and Lucas (1977). Lunzer et al's demonstration used pictures to represent four comparisons, $A > B$; $B > C$; $C > D$; $D > E$. The relationships depicted were "higher" (pictured by two kites); "in front of", i.e. "winning" (pictured by racing cars) and "heavier" (pictured by objects on see-saws). Even with all the pictures in the field showing, e.g. "the red kite is higher than the blue kite" and "the blue kite is higher than the green kite", even six-year-old subjects (the youngest subjects) showed a completely chance response to the "BD" question.

Overall, then, a consistent profile of the very young child emerges, which reflects his inability to make extensive and concatenated object descriptions even where retention is not a factor.

The thesis of Bryant and Trabasso offers an apparently "simple" or simplified account of child development eschewing the complexities inherent in, for example, Piaget's theory. However, this insistence that deductive inferential mechanisms are and must be implicated in the five-term series experiments as described by Bryant and Trabasso (1971) adds, in effect, an "extra operation" to what might be already a sufficient mechanism in the form of an <u>inductive</u> inference.

Whatever the merits or demerits of the co-ordination model, it would be unfair to imply here that the 1971 version was the only one now available. For one of the authors of that 1971 report, Tom Trabasso, has since developed a position along rather different lines (Trabasso, Riley and Wilson, 1975; Trabasso and Riley, 1975; Riley and Trabasso, 1974; Trabasso, 1975).

Trabasso has likened his own model to the "image" model of de Soto, London and Handel (1965). Trabasso's model states that subjects construct linear order using an "ends-inwards" strategy with the linguistically unmarked end being isolated first. When the end-anchored pairs are isolated they are entered into an imagined spatial array, one at either end. The other pairs are then "ordered" and entered in between the end pairs. The steps of ordered entry produces an array A B C D E. These steps constitute the encoding or storage part of the model.

During test questions this information in the array is "accessed" or retrieved in the following way: each location has a "code" for the underlying dimensional scale (of length). Each colour name is thus associated with a code C at each location in the array. It is the relative strengths of these associations that determines the direction, speed and accuracy of choices during testing. Trabasso gives a detailed account of how the relative strength of the association may be mathematically derived (Trabasso, Riley and Wilson, 1975), e.g. by

Luce's choice axiom (1959) or Murdock's theory of stimulus discriminability (Murdock, 1960). Essentially, however, the main prediction is that speed of decision is correlated with distance on the array so that the greater the distance between the items, the faster the response. This is similar to Moyer's (1973) model of "internal psychophysics" but is, as Moyer and Bayer (1976) point out, particularly interesting as it suggests that distance effects can be obtained by an entirely symbolic representation.

An important implication of Trabasso's model in the context of the current discussion is that solution does not depend on the co-ordination of the premises:

> "We believe that, indeed, children we have studied in these tasks do not use operational transitivity to solve the problem if one means by that term co-ordination of the members of the premises via a middle term at the time of testing." (Riley and Trabasso, 1975)

By contrast, Trabasso et al believe that the pairwise information is integrated prior to testing into an array composed of single items.

What evidence, therefore, is advanced by these investigators in favour of the model which they propose as an alternative to the co-ordination model? Two main sources of evidence are cited:

a) Serial position effects in training. A demonstration of the ends-inwards strategy is believed by Trabasso to be provided by the serial position effects obtained in training in which the end-pairs are learnt faster than the middle pairs. To To show that the effect is truly directional (ends to middle) and not simply due to a straightforward difference between end-pairs and (all) middle pairs, Trabasso et al have produced evidence from a six-term series problem in which it was shown that pairs (1,2) and (5,6)were learnt fastest followed by pairs (2,3) and (4,5) with pair (3,4) the slowest. Table 30 shows a sample of evidence of this nature obtained by Trabasso and his co-workers.

TABLE 30. Relative Percent Trials to Criterion

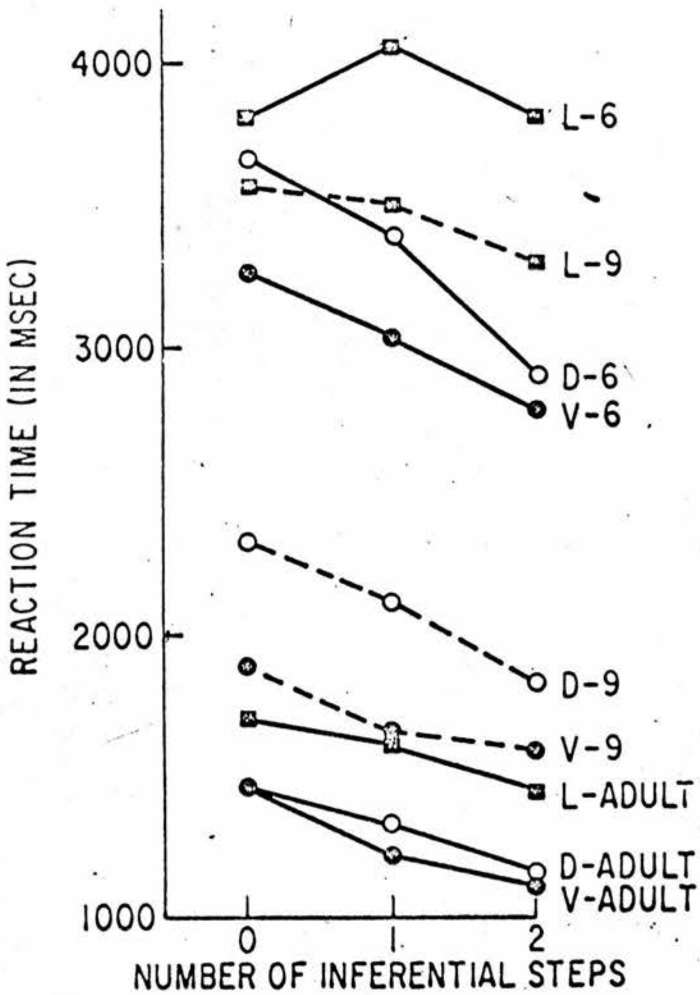
Age	Pair				
	(1,2)	(2,3)	(3,4)	(4,5)	(5,6)
6	11	24	28	26	11
9	18	23	28	23	12

(Reproduced from Trabasso, Riley and Wilson, 1975)

b) The error and reaction-time profile in testing. Test questions involving large distances are predicted, on the linear model, to show fewer errors and faster reaction times than those involving short distances. On the whole these predictions are confirmed by the data of Trabasso, Riley and Wilson (1975) in which test pairs (2,4) and (3,5) are shown to produce more errors and longer solution times than the pair (2,5) (see Figure 10, over).

A major implication of the linear model, is that single stimuli (each represented independently on the "internal" array through integration of the pairwise information) ought to be judged on a probabilistic basis in a manner which reflects their relative position on that scale, i.e. for a series in which A is the "shortest" item and E the "longest", B ought to be judged as short, C about middle, and

FIGURE 10 (Reproduced from Trabasso et al, 1975)



D ought to be judged as "long". This prediction was tested in the following experiment.

EXPERIMENT 8

SUBJECTS

The subjects were those used in Experiments 6 and 7 (minus one who was on holiday).

STIMULI AND APPARATUS

The stimuli and apparatus were identical to those used in Experiment 6.

DESIGN

Subjects were allocated to a single Verbal group. [This required re-training the Non-Verbal subjects according to the training design of Experiment 6. A full report of this procedure together with the transfer results is included in the appendix.]

PROCEDURE

Training

Subjects were re-trained (if re-training was necessary) to a performance of at least 90% correct within a session.

Testing

Subjects were shown one colour of tin at a time and asked on each presentation: "What colour does that one go with?". Each colour was represented once in six runs of five randomly ordered presentations. No feedback was given. This entire procedure was repeated using the question: "Is that a heavy one or a light one?". Finally, subjects were asked (with no stimulus in the visual field): "Which is the heaviest tin?". After responding, they were then asked: "Which is the next heaviest? and so on until subjects said that they "didn't know", or began repeating colours already given. This entire procedure was repeated using the term "lightest".

RESULTS

TABLE 31.

Judgments of "heavy" and "light" are expressed as a percentage of the total number of responses given to each stimulus. These are tabulated separately for subjects for whom A is heavy and E is light, and for subjects for whom A is light and E is heavy.

A - heavy : E - light						A - light : E - heavy					
Judgments of "Heavy"						Judgments of "Light"					
Stimulus:	A	B	C	D	E	Stimulus:	A	B	C	D	E
%	90	53	50	63	15	%	54	18	13	25	05
Judgments of "Light"						Judgments of "Heavy"					
Stimulus:	A	B	C	D	E	Stimulus:	A	B	C	D	E
%	10	47	40	37	85	%	00	67	76	54	91

Table 32 shows the number of responses for the two most frequent colour "associations" given to each stimulus. These are expressed as a percentage of the total number of associations given to each.

TABLE 32

Prime	Most Frequent "Association"	%	Second Most Frequent "Association"	%
A	B	87	E	07
B	A	49	C	39
C	B	58	D	37
D	E	59	C	29
E	D	90	C	04

Table 33 shows the "seriations" produced by each subject.

TABLE 33

Question:	"Which is the heaviest/ next heaviest", etc.	"Which is the lighest/ next lightest", etc.
Subject	For Series: A B C D E	For Series: E D C B A
1	B D A C	E D C B
2	B	E C B D
3	A B E D	D C B
4	A C D B	E
5		
6	C	E
7	B C D A E	C B D E A
8	C B C E D	D B C E
9	A E D B C	E D B C
10	A B C D	E D C
	For Series: E D C B A	For Series: A B C D E
11	E D C B A	A B C D
12	E D C	C A B A
13	E A C B A	
14	E D C B A	A D B C B
15	E C B D A	A B C D E
16		B E A D C
17	E C B D	B D B
18		A B D C
19		A D E B C

DISCUSSION

As it will be seen from Tables 31 and 32, the results of Experiment 8 do not readily lend themselves to the support of Trabasso's claim that pairwise information is integrated into a "new" linear representation on which each item is "scaled" with respect to the others. For there is no evidence that the probability of labelling a single stimulus as "heavy" or "light" reflects the relative position of that stimulus in the series as a whole. Only the end-points attract a stable and consistent "label". For the rest, the absence of any comparison stimulus leads to a labile and "fluctuating" judgment on the part of the subject. It can be seen from Table 32, furthermore, that subjects show signs of maintaining strong pairwise associations, with the end-pairs showing greater associative strengths than do the middle ones.[+]

Perhaps the strongest implication of the linear model is that subjects who show transitive choices, should also be able to "seriate" each of the items used in training. As Trabasso and Riley (1975) point out:

> " "Our findings indicate that seriation, i.e. the creation of a linear order, is critical to making inferences or at least performing well on inference tests."

[+] The "stronger" associations of B and D to the "ends" A and E than to the "middle", C, does not violate the assumption of the binary choice model which stipulates that when <u>both</u> B and D are present, then C will be inferred. This point will be returned to in Chapter Five.

Table 33 shows, however, that, despite their strongly transitive choice profile, subjects in the above experiment could not fully seriate the items when asked to do so. For no subject seriated perfectly in both directions and only three out of the nineteen seriated perfectly in one direction.

Overall, then, the evidence for "linearity" is poor. Instead, the most significant feature of the results is the prominence given to end-points as indicated by e.g. the stability of their "labels", and their high levels of associativity. "Prominence" of end-points also features in the acquisition and retention data, (see Experiment 7 which shows strong serial position effects by the end of training, with the end-pairs appearing to be easier to learn and to retain than the middle ones). Rather than claim, therefore, as do Trabasso, Riley and Wilson (1975) that such effects are "prima facie evidence for the construction or use of an underlying linear ordering of events", it is argued here that such effects reflect simply an asymmetry in the "accessibility" of the training pairs and/or individual members of those pairs.

This end-point prominence raises the spectre, moreover, of a possible artefact in Trabasso's demonstrations of the "distance effect". For his experiments involve a basic confounding of the distance of test items from the end-points of the series, with the distance of test items from each other. That is, experimental manipulation of "distance" as a variable, within a single group of subjects must inevitably produce, for every increase in "distance" between test pairs, a corresponding <u>decrease</u> in the distance of those items from their end-points. In order to estimate the effects of "distance" per se, therefore, it is necessary to compare two independent groups of subjects, each of whom learns a series of a different length. This would allow the experimenter to vary the number of inferential steps "expunged" in the tests of transitivity whilst keeping constant the distance of the test items from their end-points.

Even conceding, for a moment, that the introduction of such "controls" would leave Trabasso's claim unaffected, a further possibility still remains that the "linearity" of any representation is a direct product of "feedback". This effect could be achieved through "internalisation" of the actual physical values shown to subjects after each response. That such an operation is feasible has been demonstrated in Chapter Three. It has also been demonstrated for adults by Moyer (1973). If this possibility is correct, it would make redundant Trabasso's claim that the linear nature of the series representation is a direct consequence of the way subjects "integrate" relational information given verbally. And this possibility is in fact given further credibility by the finding of Trabasso, Riley and Wilson (1975) that young subjects of six years of age showed no "distance effects" when information was presented in a purely verbal form (see Figure 10, p.116, Condition L - 6).+

\+ Moyer and Bayer (1976) also draw attention to Trabasso's failure to obtain distance effects in their youngest group, using the linguistic condition. Moyer and Bayer are apparently puzzled as to why "symbolic" distance effects did not obtain in this group. Evidence reported in the Appendix, however, confirms the view that in the feedback conditions, the effects are not "symbolic" at all, but are based on sense-data. For example, the Non-Verbal group showed a better transfer performance to the Verbal condition on the direction specified by their previous training than they did

In any event, the main findings reported in this chapter can be summarised as follows:

a) Transitive choice profiles are produced by young children in verbal and non-verbal tests when strong and immediate feedback is given after each response.

b) Training produces, as an "accidental" result, an asymmetry of access amongst the pairs with the end-pairs being more accessible than the middle pairs.

c) Transitive choices can be predicted by the binary sampling model of McGonigle and Chalmers (1977) which exploits such asymmetry of access.

Contrary to Trabasso's claim, therefore, that transitive responses are a product of a linear representation of the training series, it is the view expressed here that transitive choices may be "induced" through the asymmetry of series representation which is essentially <u>pairwise</u>. On this view nothing more is demanded than the operation of mechanisms of <u>induction</u> found routinely in many spheres of perceptual inquiry, including those involving non-human subjects (see McGonigle and Jones, 1975, 1977a).

If inductive mechanisms are abroad therefore in the perceptual transaction by non-humans and if such inferences can underwrite

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on the other direction. The performance on the "novel" direction during triadic tests was erratic and showed an average deviation from the predictions derived from the binary sampling model of McGonigle and Chalmers (1977) of: .16 .12 .13 (on each column respectively), while the deviation on the "original" direction was: .06 .06 .08. In general, the effect of "sensed" direction was far more profound than pure lexical effects as could be seen from the relative difficulty experienced by Verbal subjects when given the series A B C D E. This difficulty appeared to be entirely due to the use of a transition which, in concrete functional terms, seemed to be an "unnatural" one for subjects. (The full details of these results are reported in the Appendix.)

transitive choice behaviour (at least under the conditions of test described here), it follows that e.g. squirrel monkeys, exposed to similar conditions of test, will show an equally transitive profile. In the next chapter experiments are described which test this prediction.

CHAPTER FIVE

That perceptual operations implicate inductive mechanisms was first proposed by Helmholtz (1925):

> "Inasmuch as in an overwhelming majority of cases, whenever the parts of the retina in the outer corner of the eye are stimulated, it has been found to be due to external light coming into the eye from the direction of the bridge of the nose, the inference we make is that it is so in every new case whenever this part of the retina is stimulated; just as we assert that every single individual now living will die, because all previous experience has shown that all men who were formerly alive have died." (1925, Vol. III, p 5)

This historical influence of prior stimulation on perceptual judgment has been emphasized since by many major perceptual theorists, e.g. Brunswick (1955), Kilpatrick (1954), Ittleson (1962), Bruner (see Bruner, Goodnow and Austin, 1966), Gregory (1970).

For Bruner (1957) an inductive inference implies "going beyond the information given", and is found in its most primitive form in routine acts of classification. Bruner (1966) writes:

> "Categorizing an event as a member of a class and thereby giving it identity involves, as we have said, an act of inference. Whether one is deciding what the blob was that appeared for a few milliseconds in a tachistoscope or what species of bird it is that we have our binoculars trained on or what Pueblo period this potsherd belongs to, the basic task is .... to make an inference." (1966, p 17)

These examples should not be taken to imply, however, that it is only the case of the degraded stimulus or a stimulus viewed under restricted conditions, that invites acts of reconstruction based on inferential mechanisms. On the contrary, Garner (1962, 1974) has shown that for perception of <u>any</u> stimulus to be adequate (however clearly and sharply depicted in purely sensory terms), it <u>must</u> be referred to some larger population or set of stimuli from which it is presumed to come. Garner (1966) states:

> "How the single stimulus is perceived is a function not so much of what it is, but is rather a function of what the total set and the subset are. The properties of the total set and the subset are also the perceived properties of the single stimulus, so we cannot understand the knowing of the single stimulus without understanding the properties of the sets within which it is contained." (1966)

A demonstration of this principle has been provided by Bruner and Minturn (1955) in which an "expectancy" based on prior exposure to a set of stimuli radically altered the perception of one presented subsequently, e.g. a stimulus was seen as a "13" when numbers were expected; on other occasions it was judged as a "B" when letters were expected.

Such demonstrations have normally been confined to studies with human subjects. However, McGonigle and Jones (1975, 1977a) have recently reported similar experiments on rats and squirrel monkeys. In their experiment, monkeys, for example, were found to polarise linear dot patterns (i.e. organise them into rows and columns) only when certain contrastives were present in the immediate visual field. Thus, a symmetrical dot matrix when paired with an asymmetrical one, allowed for polarisation of the latter, whilst no such polarisation of the asymmetrical matrix occurred when it was paired with a stimulus of plain homogeneous surface.

These findings are considered by McGonigle and Jones (1975) to confirm Garner's position expressed by him as follows:

> "What this result shows is that the immediately presented subset of two stimuli, determines the perceived properties of the stimuli in it, and the perceived properties of any single stimulus change as that stimulus is variously paired with other stimuli, since the dimension which meaningfully differentiates a pair of stimuli depends on a particular pair of stimuli involved." (1974, p 10)

In a reply to criticism from Dodwell (1977), McGonigle and Jones (1977a) have elaborated this position further to stress the implications of the <u>criteria</u> of judgment in visual organisation and retention by the perceiver. On this view such criteria are suggested to the naive perceiver in the first instance by the contrastives in the immediate perceptual field. Later, those contrastives previously associated with the stimulus (to be judged) are used as a source of reference from which the criteria of judgment may be derived.

The main implication of this view for the "five-term series" is that monkeys should learn its "connecting pairs" easily enough. For such learning depends on these very operations of comparison and contrast which McGonigle and Jones claim to be endemic to stimulus interrogation and representation by monkey. Coupled moreover with the claim expressed in Chapter Four that inductive mechanisms are sufficient in themselves to solve the "deductive" tests (of this series), the conclusion now seems inescapable that the squirrel monkey will also demonstrate a transitive choice profile in tests similar to those carried out with children.

Note

This experiment is one in which I collaborated and for which I did some of the testing. It was initiated and carried out in the main by Dr. B.O. McGonigle who designed the study to parallel those reported in Chapter Four.

EXPERIMENT 9

SUBJECTS

The subjects were eight adult male squirrel monkeys. They had extensive test experience (McGonigle and Jones, 1975, 1977 a, b) but no prior history of colour or weight discrimination training.

STIMULI AND APPARATUS

Subjects were trained and tested in a W.G.T.A. The training stimuli and the trays on which they were presented were identical to those described in Experiment 6 (p. 88).

DESIGN

The main features of the design are depicted in Table 34.

TABLE 34. Scheme of Training Paradigm

Series Identification		A	B	B	C	C	D	D	E
Pair		1		2		3		4	
Weight Order	(4 Subjects)	L	H	L	H	L	H	L	H
	(4 Subjects)	H	L	H	L	H	L	H	L
Colour+ e.g.		Y	B	B	R	R	W	W	G
Rewarded Stimulus e.g.			B		R		W		G

L = Light. H = Heavy. Y = Yellow. B = Blue. R = Red. W = White. G = Green.

+ Colour was counterbalanced according to a Latin Square Design.

PROCEDURE

Subjects were randomly assigned to one series of colour pairings (see Table 34) and one of the five trays. They were trained on each pair in the following way: a pair of tins was placed on the tray, each tin covering one of the two foodwells. Choice of one of the tins was rewarded with a peanut located in one of two foodwells directly underneath the stimuli. To indicate choice and secure the reward, the monkey had to manually displace the appropriate tin from its position over the foodwell. After an error, however, the monkey received no reward; the tray was withdrawn in full view of the subject for 5 seconds and a screen was then lowered to permit the experimenter to replace the stimulus unseen and restart testing. Training was conducted in different phases. These were as follows:

Phase I

Monkeys were trained to a performance of 9/10 correct on each pair in serial order from Pair 1 to Pair 4. This was repeated once.

Phase II

Pairs were presented in "runs" of a fixed number of trials per pair in serial order from Pair 1 to Pair 4. Five runs of 10 trials were given followed by five runs of five trials.

Phase III

Subjects were given five runs of one trial per pair.

Phase IV

Subjects were given runs of the four pairs, consisting of one trial per pair in random order. They were required to reach a performance criterion of 22 out of 24 trials correct.

Right-left location of the tins was randomly varied across trials. Approximately 50 trials were given per session and sessions were run, as far as possible, on consecutive days.

Testing

Subjects' performance on the random pairs was maintained at at least 90% correct on each pair over a given session. The "critical" test pair BD was embedded at random amongst the training pairs for not more than two trials per session. No differential feedback was given on this test pair and testing continued until 10 such trials had been administered. Left-right positions were counterbalanced across test pairs.

The five remaining binary test pairs AC, AD, AE, BE and CE were then administered. These were embedded at random amongst "runs" of the four training pairs; a procedure which continued until each test pair had been presented 10 times. The position of the tins was counterbalanced within each test series. During these tests, no differential feedback was given, i.e. the stimuli were both heavy or both light according to the previous training history of the subject. All choices were rewarded.

In the final phase of testing subjects were presented with each of the 10 triplets derived from all possible triadic combinations of the five stimuli in the original set. Five new trays, each with three foodwells, were introduced. Each session began with 25 trials involving the original training pairs presented in random runs. If not more than two errors were recorded, monkeys were then presented with each of the 10 triads, presented in counterbalanced order, for the next 25 trials. The position of each stimulus on the tray was also counterbalanced. No differential feedback was given during triadic tests. This procedure continued until each triad had been presented 10 times each.

RESULTS

All but one monkey learnt the series. The following results are reported for the remaining seven.

Table 35 shows the acquisition scores for the first and final stages of training. These show a strong serial position effect by Phase V.

TABLE 35. Percentage of Total Error

Phase I				Phase V			
AB	BC	CD	DE	AB	BC	CD	DE
25	32	20	23	09	28	51	12

Table 36 shows the binary choice profile obtained by subjects in tests of transitivity. On the crucial BD comparisons, the choices are significantly transitive.

TABLE 36.

	B	C	D	E
A	.98	1.00	1.00	1.00
B		.93	.90	.76
C			.89	.87
D				.97

All choices were significant on a Binomial Test ($p < 0.01$)

Table 37 shows the two-choice profile obtained by each individual subject. This demonstrates that transitive choice scores are obtained from all but one monkey (Green H+).

TABLE 37. Frequency of Choices to each Test Pair

	A	E	A	C	A	D	C	E	B	E	B	D
Bill L+	0	10	0	10	0	10	0	10	1	9	0	10
Bump L+	0	10	0	10	0	10	1	9	1	9	0	10
Brown L+	0	10	0	10	0	10	0	10	1	9	0	10
Broken Finger L+	0	10	0	10	0	10	0	10	1	9	0	10
Blue H+	0	10	0	10	0	10	0	10	0	10	0	10
Yellow H+	0	10	0	10	0	10	6	4	5	5	1	9
Green H+	0	10	0	10	0	10	2	8	9	1	6	4
Total	0	70	0	70	0	70	9	61	17	53	7	63

Table 38 (over) shows the triadic choice profile compared with the choice projections made by the binary sampling of McGonigle and Chalmers (1977).

Table 39 (p 128) shows the three-choice profile obtained by each subject. It is interesting to note that the only monkey whose choices are markedly intransitive during this Phase (Green H+) is also intransitive during the two-choice tests.

Table 40 (p 129) shows the overall frequency to each triad and the sum of frequencies to individual items. This provides for a global impression of the choice transitivity within the series as a whole.

TABLE 38

TRIAD	CHOICE PROJECTION			OBTAINED (Each row is based on 70 observations)		
ABC	.00	.33	.67	.00	.31	.69
BCD	.17	.33	.50	.03	.36	.61
CDE	.00	.33	.67	.11	.24	.65
ABD	.00	.50	.50	.00	.44	.56
ABE	.00	.33	.67	.00	.30	.70
ACD	.00	.33	.67	.00	.30	.70
ACE	.00	.33	.67	.00	.26	.74
ADE	.00	.33	.67	.01	.21	.78
BCE	.00	.33	.67	.06	.28	.66
BDE	.17	.17	.66	.16	.24	.60
Average Distribution	.03	.33	.64	.04	.29	.67

TABLE 39. **Frequency of Choices to each Triad**

	A	B	C	B	C	D	B	D	E	C	D	E	B	C	E	A	B	D	A	C	D	A	D	E	A	B	E	A	C	E
Bill L+	0	1	9	0	6	4	0	0	10	0	1	9	0	1	9	0	5	5	0	3	7	0	0	10	0	2	8	0	1	9
Bump L+	0	3	7	0	0	10	0	2	8	0	2	8	0	0	10	0	0	10	0	0	10	1	0	9	0	1	9	0	1	9
Brown L+	0	4	6	1	3	6	0	5	5	1	5	4	0	5	5	0	4	6	0	5	5	0	2	8	0	2	8	0	4	6
Broken Finger L+	0	9	1	1	1	8	0	2	8	0	1	9	1	0	9	0	4	6	0	2	8	0	1	9	0	2	8	0	2	8
Blue H+	0	2	8	0	3	7	0	1	9	0	0	10	0	0	10	0	4	6	0	1	9	0	2	8	0	0	10	0	2	8
Yellow H+	0	2	8	0	3	7	3	7	0	0	7	3	2	6	2	0	8	2	0	0	10	0	7	3	0	5	5	0	4	6
Green H+	0	1	9	0	9	1	8	0	2	7	1	2	1	8	1	0	6	4	0	10	0	0	3	7	0	9	1	0	4	6
Total	0	22	48	2	25	43	11	17	42	8	17	45	4	20	46	0	31	39	0	21	49	1	15	54	0	21	49	0	18	52

TABLE 40. Frequency of Choice to each Triad

TRIAD	A	B	C	D	E
ABC	0	22	48		
BCD		2	25	43	
BDE		11		17	42
CDE			8	17	45
BCE		4	20		46
ABD	0	31		39	
ACD	0		21	49	
ADE	1			15	54
ABE	0	21			49
ACE	0		18		52
TOTAL	1	91	140	180	288

DISCUSSION

The above results show that even squirrel monkeys (whose learning skills have been described by Dodwell, 1977, as little better than those of a rat!) show a transitive choice profile following training on the five-term series. Their performance is, moreover, similar in all essential details to the performance of children in the experiments reported here as well as those of Trabasso and his co-workers (see Trabasso, 1975). For, like children, the monkeys showed serial position effects in acquisition, strong end-point effect and high retention scores. It can be seen, furthermore, that there is a direct relationship between the patterns of choice in the binary and triadic phases of testing even when protocols for individual subjects are examined.[+] This concordance between the two and the three-choice profiles would militate against any suggestion that the two types of test are tapping different and quite independent processes.

Nevertheless, the transitivity of choice observed in these subjects may be explained along lines quite different to those put forward by Bryant and Trabasso (1971). For a reduced transitive effect is observed in the three-choice case and, overall, the results can be handled by the simple binary model outlined in Chapter Four. A number of factors lend support, furthermore, to the view that the fit with the sampling model is not merely "accidental". Firstly, it can be seen that apart from one "intransitive" subject, the triadic profiles of individual subjects are all concordant with the prediction that the transitive choice bias on

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+ It is particularly interesting to note that subject Green, the only "intransitive" subject, also showed a deviant profile during triadic tests.

e.g. the BD comparison, is more pronounced than in the three-choice comparison BCD. Secondly, the fit with the choice projection for each triad can be seen to be a good one - even where the prediction was somewhat unexpected as in the case of ABD. Thirdly, the main assumption on which the model itself is based (that in the case of the BD comparison, C will be inferred as a referent) is supported by evidence that B and D are each "closer" to C than they are to their respective end-points. Support for this comes from the serial position effects in acquisition which suggest that B and C, and C and D are more "confusable" than are A and B, or D and E. If, as Trabasso, Riley and Wilson (1975) suggest, we can convert relative "discriminability" into distance information, then the inference is feasible that B and D are "closer" to C than they are to A and E (respectively). Further evidence on this point comes from the apparent distances between individual items when the frequencies of response attachments to each item are summed across triads (see Table 40 on page 129). These frequencies show a "distance" between A and B and between D and E which, in both cases, is greater than the total distance between B and C, and C and D; again suggesting a primacy of "access" for C over A or E.

A final source of evidence justifying this core assumption of the binary sampling model comes from the single stimulus data from Experiment 8 reported in Chapter Four (see Table 32 on page 111). From this data, the <u>joint</u> associative strength of B and D with C can be computed by adding[+] the probability of associating C when B is the prime to the probability of associating C if D is the prime. This produces a joint associative proba-

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[+] This is done by adding the first probability (.29) to the second - expressed as a proportion of the residual uncertainty (.39x.71).

bility of B and D to C of .57 - a figure reasonably close to the .66 probability assumed in the model.

Whatever the fit of the model to the data, the binary sampling model is nevertheless open to the objection that little or no _a priori_ justification is given for the assumption that only BC and CD are "accessed" when B and D are present. Such an objection has been raised by Lunzer (personal communication) in the form of the query: "Why a zero probability should attach to the comparisons AB and DE?". This query can be catered for, however, by calculations involving extended versions of the model. From these it can be seen that the fit with the data _is_ an important criterion for assessing the viability of the assumptions of the model, for many plausible versions may be generated whose predictions do not match the empirical outcome. Take, for example, a simple version of the model which assumes in the case of the BD comparison, that both the subsets to which B and D belong have an equal probability of being sampled. In such a case it would be predicted that on 25% of all occasions A will be implicated by B's presence and that, likewise, C will be implicated on another 25% (assuming that B and D are sampled equally often). Similarly, E will be evoked by D for the remaining 25% of the time. The clear effect of such "democracy" of access would be a "cancelling out" of AB's contribution to the choice distribution on BD by BC's contribution, and, likewise, a "cancelling out" of CD by DE, thus resulting in no transitive bias whatever. On the other hand, a quite different result is predicted if the assumption is made that, whatever stimulus is responsible for evoking them, the end-points A and E will affect _both_ stimuli in the field. Thus on the 25% of all occasions that A is accessed it will have no measurable effect on the overall bias as it will confirm both B and D. Similarly, when

E is accessed by D it will disconfirm both B and D. By contrast, when C is accessed it will have an asymmetrical effect on B and D; disconfirming B and confirming D directly. This version of the model would result in a completely transitive response on 50% of all occasions and a "chance" response on the remaining 50% of all occasions, resulting in an overall transitive response to BD of 75%.

Yet another variation of the model can be produced by assuming that the end-points are best represented and thus easier to access, and also that the influence of the end-points is "generalised" (see Spence, 1937,b)+. Thus, in the case of the BD comparison, where A is accessed (pair AB), D cannot be located between A and B and will therefore be seen to lie further away from the anchor, A which, in the case of the non-verbal condition, is the only stimulus which must be avoided consistently. D is thus selected by elimination. In the case of BD, where E is accessed

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+ A model, not unlike the one proposed here has been suggested by de Boysson-Bardies and O'Regan (1973). These authors propose that a labelling-by-proximity strategy accounts for the transitive bias shown by children in the five-term series problem. That is, B "acquires" the label of A and for D "acquires" the label of E by virtue of the fact that whilst A and E have clear and consistent labels attaching to them, B and D are mere "nonentities". However, these authors produce no <u>direct</u> test of their hypothesis, i.e. by simply asking subjects to label individual stimuli following training on the four pairs. Simple "labelling" is thus only one out of the many possible alterations, and is, in fact, one which gains little support from the evidence reported here (see Chapters Two and Four).

(pair DE), B cannot be located between E and D and is therefore seen to lie outside this subset. D is thus chosen as the stimulus closest (by association) to the end-anchor E, the only stimulus to be rewarded consistently in the case of the non-verbal condition. By simple extension to verbal labels, this account is equally applicable in the verbal condition. The net result of this model would be complete, 100% transitivity.

The above variations of the model provide by no means an exhaustive set of all possible variations. Other versions can be generated by different combinations of some of those already mentioned, or even on the basis of various "conditional" models but it is not the purpose of the present account to provide an exhaustive list of all possible variations. Instead it is sufficient to point out that :

(a) the "fit" provided by the binary model as it stands is not an inevitable outcome which would be produced by any number of alternatives.

(b) the binary model can encompass a number of "extensions" which have little or no material effect on the choice predictions.

(c) there are sufficient variations to account for any differences observed between different groups of subjects (children, for example, appear to show a less marked transitive bias than do the monkeys).

Rather than conclude, therefore, like Lutkus and Trabasso (1974) that Bryant and Trabasso's experiment was "designed .... in such a way that success on the BD pair (the "symptom response") could be explained in no other way than by a transitive inference", it is suggested, instead, that the solution of the five-term series tests is open to a variety of alternative interpretations. Those considered here are basically "associative" models of thinking where an "inference" (in this context) is regarded as an act of recovery or, in Hebb's terms "a reconstruction on the basis of experience" (1949, p.47) and not as the production of "new" information. This distinction has been put succinctly by James (1891):

> "The great difference, in fact, between that simpler kind of rational thinking which consists in the concrete objects of past experience merely suggesting each other, and reasoning distinctively so called, is this that whilst the empirical thinking is only reproductive, reasoning is productive. An empirical or "rule-of-thumb" thinker can deduce nothing from the data with whose behaviour and associates he is unfamiliar. But put a reasoner amongst a set of concrete objects which he has neither seen nor heard of before, and with little time, he will make such inferences from them as will quite atone for his ignorance" (1891, page 329/330).

Thus it is the thesis presented here that the five-term series, as exploited by Bryant and Trabasso (1971) monitors some kind of association ability - not the capacity to reason deductively.

CHAPTER SIX

It is plain that the evidence reported in the previous chapters lends little support for the view that children can "reason distinctively". For, as James (1891) points out, the hallmark of such thought is that :

> "A thing inferred by reasoning need neither have been an habitual associate of the datum from which we infer it, nor need it be similar to it. It may be a thing entirely unknown to our previous experience something which no simple association of concretes could ever have evoked." (1891, p.329).

By contrast, transitive solutions produced by four to six-year-old children and squirrel monkeys can be interpreted readily enough as the product of previous and indeed very specially cultivated experience - an experience geared to produce the habitual association of which James speaks. Certainly the critical transitive solutions reported here show no ostensible sign of the "production" of novel information which would satisfy James's criterion for reasoning outlined above for (endemic to this sort of task) the response set from which the subject must respond on crucial tests is (a) provided by the experimenter, e.g. "which is taller?", "which is heavier?", etc., and (b) is cultivated during original training until the subject is "word perfect". Evidence of productive thinking must therefore be inferred from the manifestation of the "correct" (rather than the "novel") answer. However, no verification procedures are adopted to determine what steps (if any) are taken by the subject to arrive at the conclusion he reports, a conclusion which although "correct" may, as Bergmann (1957) and Cohen and Nagel (1934) have pointed out, be drawn from false premises. Unless and until such steps are carried out, the "correctness" of an answer under circumstances similar to those described in the majority of experiments reported in this thesis, may be reasonably interpreted as the product of operations of "inference" akin to those which Hebb (1949) describes as fundamental to perceptual behaviour !

> "A drawing or a report of what is seen tachistoscopically is not unlike a paleontologist's reconstruction of early man from a tooth and a rib. There is a clear effect of earlier experience filling in gaps in the actual perception, so that the end-result is either something familiar or a combination of familiar things - a reconstruction on the basis of experience." (1949, p.47).

It is in this sense then that "inferences" made by four to six-year-old children and squirrel monkeys are conceived of here: as essentially inductive and not as the product of formal deductive thinking. This is not to imply however, that any inductive "logic" is considered to be the "poor relation" of a deductive one. On the contrary, as the nineteenth century philosopher, J.S. Mill has pointed out, many inductive operations are more "truly" inferential than the so-called "strong" deductive ones. Passmore (1968) has summarised Mill's position as : (the need)

> "... to distinguish between "real" inferences and "merely verbal" transformations. Such a transition as that from 'some sovereigns are tyrants' to 'some tyrants are sovereigns' is he thinks, obviously verbal: both propositions say precisely the same thing, viz. that in some cases certain attributes 'go together'. On the other hand, inference from experience to general propositions is, Mill considers, obviously a 'real' inference: in this instance, there is that movement from the known to the previously unknown which Mill takes to be the sign of a genuinely inferential process". (1968, p.20/21)

Thus Mill believes the traditional form of the syllogism, e.g.:

All men are mortal

Socrates is a man

Therefore Socrates is mortal

to disguise the "real" inference contained in it. As Passmore puts it this "real" inference is <u>from the evidence on which our assertion about all men is based to our conclusion about Socrates</u>:

> "This evidence, according to Mill, must consist of particular observations: Smith is mortal, Brown is mortal .... From our experience in these cases we conclude that other men, Socrates for example, will also die." (1968, p.22).

Whatever the merits of Mill's "particular to general" argument it is certainly the case that the definition of "inference" has severely taxed many philosophers if not many psychologists. For Bradley (1883) and for James, an inference is the discovery of a relation. As Passmore (1968) puts it:

> "We consider the relation of A to B and of B to C; we then construct an 'ideal group' which unites A, B, C on the basis of some single principle. We note, for example, that A=B and B=C; we then combine A, B, C into a whole united by quantitative identity. In so doing we perceive the relation between A and C." (1968, p.162)

Such an inference is of "not less than two terms into one construction" (Bradley, 1883). As Bradley also points out, however, there are inferences in which there is no interposing term to link the extremes. Immediate inference is, as Passmore suggests, a case in point. Either such inferences are not true inferences at all, or they are (psychologically speaking at least) "weaker" cases. Such a case for distinguishing them in a developmental context is as strong as it is for the logician. For children as young as four may make immediate inferences: whether they infer in any other sense is open to strong doubt.

Such doubt is sustained at every stage in the argument linking the child's comprehension of relations to their ultimate co-ordination. For, as the discussion of Chapter Three indicated, there is little or no direct evidence that four year old children actually perceive relations per se. Instead, it is possible that relations, as McGonigle and Jones (1977,b) have suggested in the case of the squirrel monkey, merely determine the phenomenal content of perceptual experience (in Koffka's terms (1935) "why do things look as they do?"). For relations per se need not have, as Köhler (1930) once pointed out, any psychological status even though the determinants of what is actually perceived may be relational rather than absolute in character. +

In so far as the above distinction is a valid one, it suggests that the evidence for relational comprehension cannot be based solely on the results of tests of transposition. For the judgment of what appears equally "big", "bright", etc. - which is what much of transpositional responding may entail - does not measure comprehension of the relationships between the stimuli. The "inner union" of Köhler's is not to be confused with Bradley's "ideal group" ! the determinants of appearance with those of reason. 'Transposition' is thus, as McGonigle and Jones (1977,b) point out, first and foremost a descriptive term used to describe the behaviour of choosing, e.g. the selection of B over C when B has previously been paired with A and all three are in an ascending (size)

+ Köhler argues that organisation is essentially what Koffka (1935) has termed a "silent affair" occurring somewhere between the retina and the psychophysical field and "which are not normally experienced in the sensory field" (Köhler, 1930, p. 166).

series. What such behaviour implies is open, however, to serious question. McGonigle and Jones interpret monkeys' transpositional behaviour as implying nothing more (at least of this stage of inquiry) than the primacy of relationally-based perception. The further question, whether relations are actually perceived by the monkey, requires, they contend, a different research paradigm. For, as these authors point out, the relationship between the stimulus and response in conventional transpositional research is a purely arbitrary one, where response categories used (pointing, object displacement, etc.) have no necessary connection with the class of relationship(s) existing amongst the stimuli. In other words such stimulus relationships do not entail or prescribe any particular action (except the "directionality" of the response which can be accounted for on other grounds). This need not inevitably be the case, for the relation, e.g. "larger than" has clear and actionable implications for such operations as stacking, placing one object on top of another or inside the other, etc. - an entailment which has previously been demonstrated in Köhler's (1925) "insight" experiments where the field, once organised prescribes a set of actions which are not arbitrary but a necessary development arising out of what is perceived.

Language, of course, provides a further means to help determine what relations, if any, are apprehended by the perceiver, especially in the case of verification procedures - significantly lacking in the context of transpositional research. Certainly the relational evidence which Bryant (1973) uses to justify his claim that young children use "relative codes" does not extend to studies of verification. Instead, transposition as a choice-behavioural phenomenon is used to imply relational awareness, which the evidence, as it stands, does not justify.

It is perhaps significant that in both the cases of "transposition" and "transitivity" research the response set has been provided for the subject by the experimenter. Thus "correctness" or "appropriateness" criteria rather than those of response novelty apply here. And the psychological cause of such behaviour must be inferred, in both cases, from the direction of choices recorded, data which in themselves are mute as to their psychological cause. Thus, eschewing the problem of psychological causation, Bryant feels it necessary to invoke "memory" as the significant developmental variable. His argument might thus be paraphrased: Relative codes are primary, for "transposition" occurs along several major dimensions of change. "transitivity" implies co-ordination of relations, for the choice profile obtained cannot readily be explained on any other grounds. Therefore, given adequate retention, the young child solves the five-term series by means of deductive mechanisms.

By contrast the thesis presented here suggests that the question of "levels" remains one that must be tackled in both a comparative and a developmental sphere. Rather than subscribe to the view that "memory" is the significant variable which can be independently manipulated in developmental research, it is the view here that memory is a dependent effect which reflects the complexity and depth of stimulus processing by the subject. On this view, mere practice alone is insufficient to induce competence where none can otherwise be demonstrated.

Comparative support for such a position has recently been provided by McGonigle and Jones (1975, 1977 a,b) and in a human context by e.g. Craik and Lockhart (1972) and Sykes (1976): and it is worthy of note here that TRABASSO, one of the authors of the 1971 paper which provoked this thesis, now appears to espouse the same argument although apparently unaware of his volte face. In 1974 (Lutkus and Trabasso) he alludes to Bryant and Trabasso (1971) by saying:

"Bryant and Trabasso (1971) suggested that the failure

> of normal children (four, five or six years of age) to make transitive inferences is a production deficiency due to memory factors rather than lack of logical reasoning ability."

and yet he concludes another paper (Trabasso, Riley and Wilson, 1975) with what appears to be the contradictory statement:

> "This result is consistent with Craik and Lockhart's (1972) depth of processing argument: the more elaborate and longer lasting memory representation is that which involved "deeper" processing."

Research, then, on the "depth" or levels of processing and the representational structures which the organism generates to deal with processing would now appear a promising and fecund domain of new inquiry. "New", surprisingly, because, contrary to the impression which many psychologists may have, almost nothing is known as Vurpillot (1976) points out about the information processing capacities of children. Guided, then, by the mistakes of information-processing theorists of the past and refreshed by a re-consideration of those criteria with which to evaluate e.g. inferential behaviours which philosophers have attempted to provide, the way seems open to an intensification of work on the relationship between primary empirical experience and the elaboration of "objectification" - the conceptualisation of relationships which transcend mere conjunction, distil the essential from the accidental, and synthesise and connect what has never been seen to be connected before.

APPENDIX A

Letter sent to Dr Bryant - see Chapter Two

14th June, 1974

Dr Peter Bryant
St John's College
Oxford

Dear Peter,

As you may remember, we have been working with four year old children using the paradigm which you first reported with Trabasso in Nature 1971. Unfortunately some of the details of the apparatus and procedure are not included in this or other publications which we have read (Trabasso preprints, Bardies and O'Regan, etc.) and although it was felt at the beginning of our investigations that the information we lacked was unimportant, our subsequent failure to replicate your findings makes it imperative that we carry out as near a replication of your experiment as we can.

We should be most grateful, therefore, if you would inform us on the following points:

(1) The exact size of your box.

(2) The general procedure; in particular where it relates to the transition from the training to the test phase. Was the same (5 holes) box used during the test phase also? If a (fixed) 5 hole box was used, how did you counterbalance the position of the rods?

(3) How consistently and with what age groups did you ask 'big-little' as distinct from 'longer-shorter' questions?

(4) Did you have a rejection criterion? If so, how many subjects did you reject?

(5) Might we have more explicit details of your pre-training procedure? E.g., did E determine at this point which Ss did not understand 'longer-shorter' instructions, or was the use of different instructions decided on an age basis only?

I believe you mentioned to Margaret Chalmers that it might be possible to supply us with some of your training data. In particular we would be interested in the proportions of subjects who are at chance levels on B.D and those who are correct on all (4) trials.

Any information which you could supply us with on these points would be both welcome and interesting, particularly in the light of results which Margaret has obtained recently. These indicate that:

(a) Well over half of all subjects tested failed to complete the experiment (12 subjects were successful out of 33) using rejection criteria determined by whether (i) subjects understood 'longer-shorter' instructions as measured by performance over 6 successive trials on a pair of unpainted sticks differing in length; (ii) not more than 20 trials per pair during phase 1 training was allowed: (iii) not more than 200 trials training for all pairs involved in phase 2 testing was permitted.

(b) The results also show that out of the 12 subjects who successfully completed the training phases only 5 showed a significant bias in the direction one could predict following your own experiment.

Incidentally, I am testing monkeys on the colour-weight version of the 5 term problem - I believe I mentioned this to you when at Oxford. What do you expect? Sealed bids may be lodged not later than 30th June!

I realise that our request may be somewhat taxing, but we are keen to include in our study - particularly in the light of the results cited above - a proper replication of your conditions.

With many thanks and best wishes,

Brendan

APPENDIX B

<u>"Short" versus "long" tray effects in Experiments 6 and 7</u> - Chapter Four

During the course of Experiments 6 and 7 it was considered necessary to use a spatial "aid" in the form of a "long" tray which allowed adjacent <u>pairs</u> to be spatially dissociated. While this procedure did not appear to afford any obvious "cue", it did allow five out of ten subjects in each group to complete training. A question arose, therefore, concerning the extent to which this tray provided a significant advantage for those subjects who used it in training. As inspection of Tables 40 and 41 will reveal, the length of the tray seems somehow to be implicated as a feature affecting the test performance - for those subjects trained with the short tray show a less transitive binary choice profile than those trained with the long tray. Similarly, at least in the case of the Non-verbal subjects, the triadic choice profiles are more strongly transitive for those subjects trained with the "long tray". In the case of the Verbal subjects, however, no such effects are apparent.

TABLE 40 <u>Binary Choice Profiles for "Short-Tray" and "Long Tray" Subjects</u>

NON-VERBAL GROUP	SHORT TRAY SUBJECTS (N = 5)				LONG TRAY SUBJECTS (N = 5)			
		C	D	E		C	D	E
	A	.67	.47	.63	A	.73*	.67	.97*
	B		<u>.57</u>	.83*	B		<u>.83</u>*	.93*
	C			.73*	C			.83*
OVERALL BIAS			<u>.65</u>				<u>.83</u>	
VERBAL GROUP		C	D	E		C	D	E
	A	.50	.67	.80*	A	.54	.78*	.74*
	B		<u>.67</u>	.80*	B		<u>.87</u>*	.70
	C			.93*	C			.81*
OVERALL BIAS			<u>.73</u>				<u>.74</u>	

* Significantly above chance on a Binomial Test ($p < 0.01$)

TABLE 41 — Triadic Choice Profiles for "Short Tray" and "Long Tray" Subjects

NON-VERBAL GROUP		SHORT TRAY SUBJECTS (N = 5)			LONG TRAY SUBJECTS (N = 5)		
	ABC	.07	.30	.63	.10	.27	.63
	BCD	.20	.20	.60	.20	.27	.53
	CDE	.10	.23	.67	.23	.07	.70
	ABD	.07	.60	.30	.13	.27	.60
	BCE	.03	.57	.40	.03	.37	.60
	BDE	.37	.17	.46	.20	.23	.57
AVERAGE DISTRIBUTION		.14	.24	.52	.15	.25	.60
VERBAL GROUP		SHORT TRAY SUBJECTS (N = 5)			LONG TRAY SUBJECTS (N = 5)		
			→			→	
	ABC	.00	.47	.53	.11	.61	.28
	BCD	.19	.12	.69	.26	.26	.47
	CDE	.00	.28	.72	.11	.17	.72
	ABD	.06	.61	.23	.20	.47	.33
	BCE	.11	.22	.67	.25	.25	.50
	BDE	.10	.38	.52	.29	.29	.42
AVERAGE DISTRIBUTION		.07	.35	.58	.20	.34	.46
			←			←	
	ABC	.66	.17	.17	.50	.38	.12
	BCD	.47	.37	.16	.69	.31	.00
	CDE	.62	.24	.14	.93	.07	.00
	ABD	.53	.26	.21	.67	.17	.16
	BCE	.47	.35	.18	.67	.33	.00
	BDE	.50	.31	.19	.35	.65	.00
AVERAGE DISTRIBUTION		.54	.28	.18	.64	.32	.04

To explore the possibility further, that the "tong tray" training enhances test performance, "short tray" subjects were involved in a re-training phase which occurred between Experiments 7 and 8.

RE-TRAINING PHASE

Subjects from both groups who had been trained and tested on the short tray were given 24 training trials on the long tray as in Phase V of the training procedure outlined in Experiment 6. If no errors were recorded, they were given binary and triadic tests exactly as the other long tray subjects had been given them.

RESULTS

All subjects showed perfect transfer on the first 24 trials. Tables 42 and 43 show the test performances before and after re-training.

TABLE 42 Binary Choice Profiles before and after re-training on the long tray

		SHORT TRAY SUBJECTS				SHORT TRAY SUBJECTS AFTER RE-TRAINING ON LONG TRAY		
		C	D	E		C	D	E
NON-VERBAL GROUP	A	.67	.47	.63	A	.90*	.57	.67
	B		.57	.83*	B		.60	.70
	C			.73*	C			.70
OVERALL BIAS			.65*				.69*	
VERBAL GROUP		C	D	E		C	D	E
	A	.50	.67	.80*	A	.73*	.67	.80*
	B		.67	.80*	B		.63	.80*
	C			.93*	C			1.00*
OVERALL BIAS			.73*				.77*	

* Significantly above change on a Binomial Test (p< 0.01)

TABLE 43 **Triadic Choice Profiles Before and After Re-training on the Long Tray**

		SHORT TRAY SUBJECTS			SHORT TRAY SUBJECTS AFTER RE-TRAINING ON LONG TRAY		
NON-VERBAL GROUP							
	ABC	.07	.30	.63	.00	.27	.73
	BCD	.20	.20	.60	.23	.23	.54
	CDE	.10	.23	.67	.10	.13	.77
	ABD	.07	.60	.33	.00	.40	.60
	BCE	.03	.57	.40	.10	.40	.50
	BDE	.37	.17	.46	.10	.33	.57
AVERAGE DISTRIBUTION		.14	.24	.52	.09	.29	.62
VERBAL GROUP		SHORT TRAY SUBJECTS			SHORT TRAY SUBJECTS AFTER RE-TRAINING ON LONG TRAY		
		→			→		
	ABC	.00	.47	.53	.00	.44	.56
	BCD	.19	.12	.69	.22	.28	.58
	CDE	.00	.28	.72	.06	.11	.83
	ABD	.06	.61	.33	.00	.65	.35
	BCE	.11	.22	.67	.17	.39	.44
	BDE	.10	.38	.52	.17	.22	.61
AVERAGE DISTRIBUTION		.07	.35	.58	.10	.34	.56
		←			←		
	ABC	.50	.38	.12	.69	.12	.19
	BCD	.69	.31	.00	.69	.25	.06
	CDE	.93	.07	.00	.65	.35	.00
	ABD	.67	.17	.16	.68	.16	.16
	BCE	.67	.33	.00	.67	.28	.05
	BDE	.35	.65	.00	.39	.50	.11
AVERAGE DISTRIBUTION		.64	.32	.04	.63	.28	.09

CONCLUSIONS

The results partially confirm the suggestion that training on the long tray produces an enhanced transitive effect. However, this view is not supported by the triadic data for the Verbal subjects and the overall results are, thus, inconclusive. Lack of time and direct relevance to the issue in hand prevented a more rigorous exploration of the spatial effects.

APPENDIX C

The Procedure and Results of Re-training the Non-Verbal subjects on the Verbal condition of Experiment 6 (Chapter Four)

RE-TRAINING PROCEDURE

Subjects from the non-verbal group were given one session of verbally administered training trials according to Phase V of the procedure of Experiment 6 (Chapter Four). All (nine) subjects showed perfect transfer and made no errors. Binary and Triadic tests were then administered as for the verbal group of Experiment 6.

RESULTS

TABLE 44 The Binary Choice Profile of Verbal "Transfer" subjects.

	B	C	D	E
A	1.00*	.72*	.74*	.85*
B		.96*	.56	.78*
C			.95*	.81*
D				.98*

*Significantly above chance on a Binomial Test ($p \leq 0.01$)

A strong transitive bias is shown on all the test pairs except the crucial one BD. Whilst this might suggest an overall lack of conservation of response to BD from the non-verbal to the verbal situation, it can be seen from the individual scores that this was not the case (Table 45).

The triadic choice data indicates a strong positive "transfer" of transitive responding, as can be seen from Table 46.

Table 47 shows that there is greater concordance with the projections from the binary model in the case where the direction specified by the non-verbal training procedure, i.e. A $\rightarrow$ E.

TABLE 45 Transitive Choices Frequencies on BD.

Subject	Non-Verbal →	Verbal
1	0	0
2	0	1
3	2	2
4 *	5	0
5	5	5
6	6	5
7	6	6
8	6	6
9	6	6

* - Subject who did not transfer his choice bias.

TABLE 46 The Triadic Choice Profile of Verbal "Transfer" subjects.

←	←		TRIAD		→	→
.62	.26	.12	ABC	.03	.28	.69
.79	.64	.17	BCD	.06	.29	.65
.47	.33	.20	CDE	.03	.34	.62
.86	.04	.10	ABD	.03	.43	.54
.57	.20	.23	BCE	.09	.44	.47
.39	.45	.16	BDE	.13	.23	.64
.62	.22	.16	AVERAGE DISTRIBUTION	.06	.34	.60

<u>TABLE 47</u> Deviations from Choice Projections for both Directions (⟶ and ⟵).

A. Where non-verbal and verbal directions are congruent (i.e. ⟶).

TRIAD	DEVIATION		
ABC	.03	.05	.02
BCD	.11	.04	.15
CDE	.03	.01	.05
ABD	.03	.07	.04
BCE	.09	.11	.20
BDE	.04	.06	.03
AVERAGE DEVIATION	.06	.06	.08

B. Where non-verbal and verbal directions are non-congruent (i.e. ⟵).

TRIAD	DEVIATION		
ABC	.05	.07	.12
BCD	.29	.31	.00
CDE	.20	.00	.20
ABD	.20	.13	.07
BCE	.10	.13	.23
BDE	.11	.05	.16
AVERAGE DEVIATION	.16	.12	.13

DISCUSSION

The resultx are consistent with the view that no particular difficulty attaches to the verbal condition of test when a strong non-verbal basis for discrimination exists. This view is reinforced by the finding that experience with a particular "sensed" direction of change in a non-verbal task can promote strong positive transfer (measured here by concordance with the binary sampling model's triadic "projections") to its corresponding verbally administered task.

Two further findings support the view that the nature of "sensed" relationships is more critical to the performance on the verbal task than the nature of the linguistic relations themselves. These are

(a) that no pure "lexical" effects (see Clark, 1969a) were apparent in the training scores of the original verbal group. The total errors across all phases of training for this group were 288 and 290 per Heavy and Light respectively.

(b) that one direction of stimulus was markedly more difficult than the other. That B, subjects from whom A was heavy and E was light took longer to learn the series than subjects for whom A was light and E was heavy. Whilst seven out of the former sub-group of subjects required the long tray in training only 3 of the latter group showed a need for this training "aid". As can be seen from Table 48 furthermore, the error scores also show an asymmetry between the group.

TABLE 48 Total Number of Errors During Acquisition.

	A-heavy → E-light	A-light → E-heavy
Verbal Group	396	182
Non-Verbal Group	431	337

No "lexical" theory could readily explain such asymmetrics. By contrast, it can be noted that the sub-group differences are consistent with the "feature positive" hypothesis of Jenkins (1967), which states that a discrimination is more readily learned if the positive stimulus has a physically distinctive feature. If, in the above case, the "positive" stimulus is the "next" or novel one, and the "feature-full" stimulus is taken to be the heavy one (this stimulus had sand in it and "rattled" a good deal), then it can be seen that the direction of asymmetry is in accord with the feature positive hypothesis. Further support for this comes from the acquisition scores for the verbal group for whom, direct relationship was observed between the series direction and performance on the "positive" stimulus (despite the overall difference across the two series directions). That is, those (five) subjects for whom the "novel" stimulus was always heavy, made more errors on light than on heavy, while those (five) subjects for whom the opposite was the case, made more errors on heavy than on light. The difference between these sub-groups was significant (x^2 sig. at $p < 0.02$, d.f = 1).

Table 2 Concentration of unsaturated acids

Acid	Percentage of total acids*	Concentration (μg per 100g sediment)	Acid	Percentage of total acids	Concentration (μg per 100 g sediment)
12: 1†	0.12	1.55	17: 2†	0.28	3.64
14: 1ω7	0.24	3.26	18: 2ω6	1.34	18.0
14: 1ω5	0.12	1.54	16: 3ω4§	1.28	17.1
15: 1ω8	0.30	3.97	18: 3ω3	0.45	6.03
15: 1ω6	0.42	5.56	18: 3ω6	0.86	11.6
iso 15: 1	0.11	1.51	20: 3ω6	0.43	5.76
anteiso 15: 1	0.04	0.48	18: 4ω3	0.76	10.1
16: 1ω7	29.2	390	20: 4 ω6	8.39	112
16: 1ω5	0.55	7.36	22: 4ω6	0.25	3.37
iso 16: 1‡	0.06	0.83	20: 5ω3	7.30	97.8
17: 1ω8	2.14	28.7	22: 5ω3	0.12	1.66
17: 1ω6	0.45	6.02			
iso 17: 1‡	0.25	3.29	t16: 1ω7	0.27	3.56
anteiso 17: 1	0.09	1.17	t16: 1ω13	0.47	6.32
18: 1ω9	1.88	25.2	t18:1ω7	0.14	1.89
18: 1ω7	3.30	44.2	t18: 1ω9	0.11	1.51
16: 2ω4	1.26	16.9			
16: 2ω7	0.87	11.6			

* Data quoted to two decimals is only used to indicate the ratio of minor components. Actual accuracy is about 15% and the values are corrected for the slight loss of unsaturated acids on the capillary columns. † Two unidentified isomers. ‡ Mainly Δ^9. § Trace ω3 and ω6 isomers.

in each case were *trans*. In our sediment the percentage of the *cis* isomer is larger (99% for 16 : 1, 95% for 18 : 1) and the proportion of *cis* and *trans* for each positional 16 : 1 and 18 : 1 isomer varies significantly. The range of *trans* acids in the sediment seems to parallel the range of the corresponding *cis* isomers but the very low concentrations encountered here have prevented us from obtaining unequivocal identifications. These acids and the change of the *cis–trans* ratio with depth are under study. The other *trans* isomer isolated, t16 : 1ω13, is probably of biological origin. This acid has not previously been reported from a sediment, despite its ubiquity in photosynthetic organisms where it is found localised in the chloroplast phosphatidyl glycerol fraction[15]. This acid may prove to be a good marker for a contribution from photosynthetic organisms.

This report shows that a detailed study of the gross fatty acid patterns can be combined with the isomeric forms of these acids to be of value to the environmentalist in relating isolates to probable origin. In our case diatoms and marine bacteria are strongly implicated as the major contributors of organic carbon to this typical, temperate intertidal zone sediment.

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Are monkeys logical?

THE monkey's status as a thinker has never been high; yet laboratory investigations testify, nevertheless, to the ability of many species of monkey to learn complex tasks, if not to reason. On this latter point, however, hard evidence is significantly lacking. One reason for this is that it is difficult to devise tests which are both meaningful to non-verbal subjects yet satisfy the stringent requirements of a formal reasoning test such as one adapted from Burt[1] which first gives the subject the following information: "Edith is fairer than Suzanne", "Edith is darker than Lili", and then requires solution of the question, "which is the darkest, Edith, Suzanne or Lili?". Bryant and Trabasso[2] have devised a simplified method of giving such tests to very young children, and we have adapted this into a non-verbal one for use with monkeys.

In Bryant and Trabasso's study, children were first trained to label five rods presented in four subsets as big or small according to the colour and the subsets in which they were embedded. As displayed, however, no size differences were apparent. Thus, for example, a yellow rod (A) was taught as 'taller than' a red one (B), a red one as 'taller than' a blue one (C), a blue rod was learnt as 'taller than' a green one (D), and a green one as 'taller than' a white one (E). On subsequent tests, children were asked to judge the relative sizes of non-adjacent members of the set, for example red (B) against green (D).

Eight adult squirrel monkeys were tested in an apparatus (a Visconsin General Testing Apparatus) which allowed the monkey to view on any one trial, a tray bearing two cylindrical tin containers of equal size but differing in colour and weight. The experimental design is depicted in Table 1. Each monkey was confronted with four pairs of colour discriminations, learnt serially. For half the subjects the rewarded stimulus was heavier than the non-rewarded one; for the other half it was the lighter one. Weight differences were used to emphasise stimulus differences in the course of preliminary training[3]. Only two weight values were used throughout the experiment, however; the 'heavy' tin in any pair was filled with lead shot, the 'light' one was empty. Thus, no specific weight could be uniquely identified with stimuli B, C and D.

Monkeys were assigned to different colour pairings and the tray colour was also varied from monkey to monkey in an attempt to eliminate fortuitous colour preferences which might affect the crucial test choices. Each pair was

Table 1 Scheme of training paradigm

Series identification		A	B	B	C	C	D	D	E
Pair		1		2		3		4	
Weight	4 subjects	Light	Heavy	Light	Heavy	Light	Heavy	Light	Heavy
	4 subjects	Heavy	Light	Heavy	Light	Heavy	Light	Heavy	Light
Colour (for example)		Yellow	Blue	Blue	Green	Green	Red	Red	White

learnt in serial order from AB to DE to a criterion of 18/20 trials correct for each pair. Choice of one of the tins was rewarded with a peanut located in one of two foodwells directly underneath the stimuli. To indicate choice and secure the reward, the monkey had to manually displace the appropriate tin from its position over the foodwell. After an error, however, the monkey received no reward; the tray was withdrawn in full view of the subject for 5 s, and a screen was then lowered to permit the experimenter to replace the stimulus unseen and restart testing. The respective positions of the stimuli varied from the left to the right of the tray according to a random sequence.

When subjects had learnt all four pairs they were given a second run through all problems in the same order to the same performance criterion. Several subsequent runs then followed in which the number of training trials given per problem was progressively reduced. Finally, five runs were given of one trial per problem in a random order of presentation. A maximum of 50 trials per day was administered. When each monkey had progressed through all stages of the procedure outlined above, it was given a series of 10 critical trials on the B against D comparison (see Table 1). 'Critical' tests, however, were not administered in any session until the animal first recorded a performance of 22/24 correct in the course of 24 successive encounters of training pairs in a random sequence; not more than two transitive tests were administered per session. All choices were rewarded irrespective of bias during the testing phase. When the B against D tests were complete, subjects were given further tests in similar conditions with the AC, AD, AE, CE and BE combinations in counterbalanced order of presentation (these are regarded as less critical as they include stimuli A and E which can be identified as having been invariably rewarded (E) or invariably non-rewarded (A)). All but one monkey learnt the series; the eighth was erratic and did not meet our stringent training criteria sufficiently often to warrant subsequent testing.

In Table 2 the monkey results are compared with the child data obtained by Bryant and Trabasso for 4-yr-old children. These data clearly show a choice profile consistent with the notion that monkey choices are transitive and accord in virtually every detail with the data reported for children.

Are we to assume, therefore, that monkeys solve such problems by means of deductive inference? Certainly the evidence is consistent with the idea that in order to solve such problems, subjects must coordinate two vital pieces of information—for example that C is heavier than B, and that D is heavier than C. There are alternative ways in which the problem might be solved, however. Among these[4], the one which is perhaps the most radically at odds with the coordination model[3] assumes that transitive choices result from single binary decision making.

A set BCD, for example, affords three subsets, BC, CD and BD. If a decision is based exclusively on the interrogation of any one subset, and if we assume (in the absence of information to the contrary) that each subset is interrogated equally often, then it is possible to compute the choice proportions to each of the constituent members of the triad BCD on a given trial. If, therefore, the probability of selecting any one of the subsets as a basis for choice is 0.33 (approximately) we can thus predict an overall choice proportion of 0.33 in the case of C (assuming absolute preference for C over B). D has two reference subsets, CD and BD. In the case of subset CD (making the same assumptions as above) the choice proportion predicted for D will be approximately 33%. In the case of subset BD, however, we need assume no consistent preference for either B or D. On the 33% of all occasions on which these comparisons are made, the subject may select either one equally often. In this case, the overall probability of choosing D would rise by a further 16% (with roughly 16% of all choices going to B). Thus we might predict the approximate choice proportions for all three stimuli in the set BCD as follows: $B = 0.17$, $C = 0.33$ and $D = 0.50$.

In a two-choice situation, of course, where B is presented in conjunction with D, C would have to be 'inferred' as a referent (an assumption in common with the coordination model, some theories of perception[5], and of transitivity[6] and a reasonable one given the duplicate relationship of C with B and D). In this instance the choice proportions attributable to C when actually present will now add to the overall proportions for D (as half of them will rule out responses to B, the other half will confirm D directly). Thus the probability values for BD in a two-choice situation will now be: $B = 0.17$, $D = 0.83$.

In the case of comparisons involving an endpoint value, however, (either A or E), fewer subsets will be at chance levels of choice (taking as a total population all 10 triadic permutations of the 5 term series A, B, C, D and E); thus the projection for the average transitive choice proportion is 0.98. Such predictions seem a remarkably close fit to data already obtained in various experiments reported to date (Table 3).

Apart from fitting predictions to existing data, however, to provide an alternative account to the coordination model, there is an empirical test of the relative strengths of these opposed accounts which is made possible if three

Table 2 Transitive choice data for squirrel monkeys compared with the profile reported by Bryant and Trabasso[8] for 4-yr-old children.

	Monkeys					4-yr-old children (B+T) (Experiment 1)			
	B	C	D	E		B	C	D	E
A	0.98	1.00	1.00	1.00	A	0.96	0.96	0.93	0.98
B	—	0.93	0.90	0.76	B	—	0.92	0.78	0.92
C	—	—	0.89	0.87	C	—	—	0.90	0.94
D	—	—	—	0.97	D	—	—	—	0.91

All choices reported for monkeys are significant on a binomial test ($P < 0.001$). Note especially the B against D comparisons which cannot depend directly on 'end-anchoring' effects.

Table 3 Averaged transitive choice data taken from three separate investigations (choice proportions)

Investigation	Choice proportions to pairs with end points	Proportions to the 'critical' pair (BD)	Overall transitive choice proportion
Bryant and Trabasso[2] experiments 1 and 2 (5 groups)	0.96 (0.98)	0.85 (0.83)	0.94 (0.96)
de Boysson-Bardies and O'Regan[7] experiments 1 and 2 (2 groups)	0.91 (0.98)	0.82 (0.83)	0.90 (0.96)
This work (1 group)	0.93 (0.98)	0.90 (0.83)	0.92 (0.96)
Average (all investigations)	0.95 (0.98)	0.85 (0.83)	0.93 (0.96)

Values in parentheses are predicted values from a binary choice model (basis of computation outlined in Table 4).

(or more) stimuli, for example B+C+D, are actually presented to the subject for choice following establishment of strong preferences within subsets BC and CD. On the coordination model it is not readily apparent why the actual presentation of the three relevant terms would do other than emphasise further the choice bias in favour of D obtained in the course of two-choice transitivity tests (for example BD). On the binary sampling model, however, a 'reduced' transitive effect is demanded whereas no such predictions are afforded by the coordination theory. We report below a direct test of these positions.

The seven remaining monkeys were presented with 10 triplets derived from all possible triadic combinations of the five stimuli in the original set (A, B, C, D and E). Each session began with 25 trials involving the original training pairs presented in random order. If not more than two errors were recorded, monkeys were then confronted with a three-choice situation where, for another 25 trials per session, each of the 10 triplets was presented in a counterbalanced order. The position of each stimulus on the tray was also counterbalanced. The stimuli were either all 'heavy' or 'light' in accordance with the previous training history of the animal. All choices were rewarded, and the experiment was terminated when subjects made 10 separate choices to each of the 10 triplets presented for test.

Table 4 Profile of choice following triadic presentations

Triads	Choice projection*			Obtained		
ABC	00	33	67	00	31	69
BCD	17	33	50	03	36	61
BDE	17	17	67	16	24	60
CDE	00	33	67	11	24	65
BCE	00	33	67	06	28	66
ABD	00	50	50	00	44	56
ACD	00	33	67	00	30	70
ADE	00	33	67	01	21	78
ABE	00	33	67	00	30	70
ACE	00	33	67	00	26	74
Average distribution	0.03	0.33	0.64	0.04	0.29	0.67

The figures in the left-hand column are predictions based on the assumptions that the subsets are sampled equally often and that preferences are absolute within those subsets presented during original training.

*Basis for predictions in Table 3.

Table 4 shows the overall choice profile in these conditions, and shows how the response distributions for triads are well predicted from a binary (statistical) decision model. By contrast, a coordination model[2] does not readily lend itself to any quantifiable prediction of a reduced transitive effect. On the contrary, with the relevant choice items in the immediate perceptual field, the 'transitive' choices should, if anything, be all the more pronounced.

Whatever the case for, or against, deductive reasoning which may be fashioned from results such as those reported here, it is clear that some kind of 'inference' necessary to produce the appropriate 'inferred' set or absent referent is used by monkey in tests of transitivity such as those described here. Whether such operations (of 'inference') provide for the foundations of logical development remains unknown.

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Dissolved ATP in the sea and its utilisation by marine bacteria

The biologically labile fraction of the dissolved organic matter (DOM) in the oceans seems to be a chemically complex solution of a wide variety of compounds derived mainly from the contents of cellular metabolic pools released into the seawater after the death and cell lysis of marine organisms. This fraction is of particular geochemical interest because of its importance in understanding the cycling of organic matter in the marine environment. Because of methodological problems arising from the extremely low concentrations of individual compounds, compound-specific analyses have been limited to only a few components of the DOM, such as amino acids[1], lipids[2], sugars[3], and vitamins[3]. Adenosine-5′-triphosphate (ATP) would be a useful tracer for following the production and fate of labile DOM in seawater as it is a universal component of the cellular metabolic pools of all living organisms. We report here that dissolved ATP (DATP) occurs in seawater in significant concentrations (0.1–0.6 $\mu g\ l^{-1}$) and is utilised rapidly by marine bacteria.

Although the particulate ATP content of marine seston (suspended particles) has been used extensively as a sensitive indicator of microbial biomass in oceans and lakes[4], the presence of DATP in seawater had not been demonstrated conclusively[5]. This has been due, in part, to the absence of a suitably sensitive method, and, in part, to the general assumption that ATP is so rapidly degraded by transphosphorylases and ATPases after cell death as to preclude its presence in the DOM. We considered that the rate of enzymatic breakdown of DATP in the sea might be negligible because extreme dilution of both the enzymes and the substrate occurs after cell disruption.

DATP concentrations in coastal waters of Southern California and British Columbia, Canada were measured using a modification of the method of Hodson *et al.*[6], which was developed originally for determination of ATP associated with organisms in marine sediments. Seawater samples (50 or 100 ml) were first filtered through 0.2 μm Nuclepore filters to remove ATP associated with organisms and other particles. Filtrates were acidified to 0.6 N with sulphuric acid. A trace amount of γ-^{32}P-ATP (less than 1 nCi per sample; 700 Ci $mmol^{-1}$) was added as an internal standard and the sample was passed through a column of activated charcoal. Adsorbed ATP was then eluted with

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